Name	Presentation title	Presentation Abstract
Abhinna Kumar Behera	Retrieval of high spatial resolution black carbon sources: use of the adjoint GEOS-CHEM model in conjunction with WRF-CHEM calculations to improve the emission pattern in Europe	Black carbon (BC) is a short-lived climate pollutant that absorbs sunlight and warms the atmosphere. It also reduces the albedo of snow and ice, which further contributes to warming. Furthermore, the effects of BC on cloud microphysics and precipitation are not fully understood. BC is emitted from a variety of sources, including fossil fuel combustion, biomass burning, and forest fires. The high-resolution sources of BC emissions are not well established, which impedes reducing the uncertainties of its climate impacts. Inverse modeling is essential for understanding the extent of uncertainty surrounding BC's repercussions at both global and regional scales. In this study, we use a grid-nesting strategy to identify BC emission sources across France in 2019 and 2020. The strategy uses a spatial resolution of 0.25° (latitude) x 0.3125° (longitude) for Europe. The GEOS-CHEM global chemistry-transport model (CTM) and its adjoint are coupled with the 4D-Var assimilation technique. For data assimilation, we use Sentinel-5P/TROPOMI aerosol products developed by the GRASP algorithm, with a particular focus on absorbing aerosols, and in situ measurements of BC surface concentration. We use the retrieved high-resolution BC emissions to initialize and drive the WRF-CHEM regional CTM. We use grid nesting to focus on the Paris area at a spatial resolution of 1x1 km². This allows us to demonstrate BC transport and its regional adverse effects. BC is a small fraction of total aerosol emissions and can be transported over long distances. This makes it difficult to measure and attribute emissions to specific sources. Therefore, we use separate ground-based measurements from various Parisian sites for validation. This work is expected to improve BC emission characterization and is consistent with restricting BC emission sources from multiple countries for an efficient climate mitigation policy with climate intervention strategies.
Adam Varble	Differences Between E3SM Simulated and Observationally Retrieved Aerosol-Liquid Cloud Relationships are Modulated by Cloud Adiabaticity	We use 5 years of observational retrievals with output from the U.S. Department of Energy (DOE) Energy Exascale Earth System Model version 1 (E3SMv1) at the DOE Atmospheric Radiation Measurement Eastern North Atlantic site in the Azores to compare observed and simulated relationships between cloud optical depth (COD), cloud droplet concentration (Nd), liquid water path (LWP), and cloud condensation nuclei concentration (CCN) that affect COD susceptibility. Observational datasets use either top-of-atmosphere (TOA) or surface-based remote sensing measurements with commonly employed assumptions and are analyzed across multiple resolutions. E3SMv1 datasets estimate Nd using either direct model output, assumptions consistent with the TOA observational retrievals, or assumptions consistent with the surface observational retrievals. Nd retrieval assumptions substantially contribute to spreads in the comparisons between various model and observation datasets, and a key parameter that varies across the retrievals with substantial impacts on COD susceptibility terms is cloud adiabaticity. Adiabaticity is assumed to be constant in TOA retrievals, whereas it is allowed to vary in surface retrievals. E3SMv1's adiabaticities are much lower than those retrieved by surface observations and 80% assumed for TOA measurements. This decreases both the COD sensitivity to Nd and the COD response to CCN, thus muting the Twomey effect relative to what they would be for higher and less variable adiabaticities. This happens because a constant adiabaticity narrows the retrieved lnNd distribution relative to one that allows a distribution of adiabaticity values, thus increasing sensitivities involving lnNd. If adiabaticity is set to the same constant value in all datasets, a greater Twomey effect than observed emerges in E3SMv1 in association with a greater sensitivity of Nd to CCN. Adiabaticity differences also affect interpretation of the LWP response to Nd. This relationship in E3SMv1 is overall negative as observed, but observed clouds become more adiabatic as Nd increases while E3SMv1 clouds do not. This indicates that the negative LWP-Nd relationship is potentially not caused by the same mechanisms in E3SMv1 and observations. The simulated negative LWP response also fails to mute the excessive Twomey effect as would be expected if it were causal, highlighting possible confounding factors that affect the LWP-Nd relationship. These findings highlight the importance of understanding how retrieval and cause-effect assumptions affect interpretations of aerosol-cloud relationships and evaluation of such relationships in models.
Allison Collow	Challenges in Observing, Modeling, and Forecasting the June 2023 Smoke Event over the Northeast United States	In the first week of May 2023, boreal Canada began an early start to the biomass burning season when fires erupted across Alberta and western Saskatchewan. Smoke entered the troposphere and spread across the United States as biomass burning emissions in Canada quadrupled the prior maximum since the onset of the MODIS satellite record. Adding to the already existing smoke, wildfires ignited in Quebec on June 2, 2023, producing a heavy plume of aerosol over the northeastern part of the continent. Meteorological factors, including an area of low pressure situated, nearly stationary, over Maine, transported the smoke into a densely populated corridor containing the cities of Washington, DC, Baltimore, Philadelphia, and New York City. Air quality alerts became widespread as near-surface levels of fine particulate matter (PM2.5) exceeded harmful levels due the low altitude of the smoke plume. Forecasting the smoke transport and impacts of such events requires a complex combination of observed initial conditions for meteorology and aerosols, knowledge of the emissions from wildfires, and a state-of-the-art Earth System model that couples these components together. Using a case-study perspective with the Goddard Earth Observing System (GEOS), challenges associated with near real time forecasting of the smoke plume are presented. Analyzed and forecasted aerosol optical depth will be evaluated using available satellite and AERONET observations, while surface aerosol will be assessed relative to observations of PM2.5. Lacking real time estimates of biomass burning emissions for inputs to our forecast model, particular attention is given to the use of day-old biomass burning emissions throughout the forecast period covering the first ten days in June 2023, and the resulting reduction in forecast skill will be quantified.
Andrew Gettelman	Reducing Ship Emissions Accelerates Global Warming	In 2020 the International Maritime Organization (IMO) instituted new regulations limiting the sulfur content of fuel in ships (IMO2020) regulations. Evidence indicates that this has dramatically reduced visible ship tracks, similar to earlier regulations in specific emissions zones near populated coasts. This work is assessing what we have observed, and what we can simulate about the impacts of the IMO2020 regulations on clouds and radiative forcing of climate through aerosol-cloud interactions in visible and non-visible ship tracks. There is solid observational evidence that there has been a reduction in ship tracks. Simulations indicate a small climate effect of ship emissions (cooling) with a warming estimated from the IMO2020 changes. Simulations from multiple models have been assessed, but more work is welcome. This warming brings forward expected reductions in aerosol radiative forcing and is expected to have slightly accelerated anthropogenic radiative forcing and climate change.

Name	Presentation title	Presentation Abstract
Andrew Sayer	On spatial scales of variation in aerosol optical depth fields	Satellite level 3 aggregates and model output are often provided at horizontal spatial resolutions of 1 degree. This convention arises more from logistical and historical reasons than considerations about the natural magnitudes and spatial scales of variations in aerosol fields. We present some initial work into these natural scales of variation using variogram and related analyses. While our end goal is not yet fully solidified, a better understanding can help researchers in several ways. Examples include more objective spatial scales for aggregates; understanding sampling and representation-related uncertainties in them; assisting interpretation of satellite-model comparisons; and formulating spatial uncertainty covariance fields for data assimilation applications.
Calvin Howes	Identifying and Reducing Uncertainties in Smoke-Stratocumulus Interactions in Multiple Climate Models in the Southeastern Atlantic Using Field Campaign Observations	The southeast Atlantic Ocean (SEA) provides an excellent natural laboratory to study smoke-cloud interactions, a large driver of uncertainty in climate projections. This region features near-permanent stratocumulus clouds and a massive persistent smoke source during the agricultural burning in the Austral winter. The physicochemical evolution of the smoke, its transport, as well as its tendency to function as CCN in warm clouds all present important targets to constrain uncertainty in predictions of aerosol's climate impacts. In this work, we compare observations from the ORACLES, CLARIFY, and LASIC field campaigns to study representation of these processes in two earth system models (CESM and E3SM) and a regional climate model (WRF-Chem-CAM5). Using airborne measurements of 3D-winds, clouds, and aerosols, we find that there is a strong sensitivity of modeled cloud droplet number concentration (CDNC) to marine boundary layer (MBL) turbulence, both in the mean turbulent updraft velocity and its distribution, which together drive model CDNC biases. We also find model uncertainties in the representation of smoke aging in the free-troposphere, with models not displaying the observed loss of organic aerosol (OA) and decrease in mean particle diameter, biases which manifest in MBL smoke once it entrains. Finally, models overpredict smoke concentrations in the MBL, likely associated with too-weak wet removal. Sensitivity simulations will be shown aimed at improving model representation of these processes in the multiple modeling systems, such as modifying turbulent updrafts, OA loss parameterizations, and updated cloud microphysics schemes. These results have cascading effects on representation of cloud brightness and lifetime in different cloud regimes and the stratocumulus-to-cumulus transition in this key region. Additionally, they may help inform modeling of aerosol-cloud-radiation interactions on a climatic scale by targeting these major sources of uncertainty.
Caroline Poulsen	Evaluation of extreme smoke plumes during 2019/2020 Australian fires and future operational applications	The frequency of Australian bushfires is expected to increase as the climate changes. In Australia the smoke from bushfires has a negative impact on air quality. During the Black summer fires of 2019/2020 over 400 deaths during were linked to smoke inhalation. Furthermore the radiative effects of the smoke can have a significant impact on fire weather as well as impacting solar energy monitoring and generation. In this presentation we outline the operational applications of measuring aerosols in Australia. We examine the quality of satellite retrievals during this period from by comparing satellite observations from MODIS, SLSTR and Himawari. The AOD retrievals are evaluated against the Tumbarumba Aeronet site. The comparison shows the difficulty in identifying plumes greater than approx. 2-4 AOD. Using Himawari data a retrieval of extreme biomass plumes (AOD >4) is demonstrated using a modified cloud ORAC cloud retrieval. Smoke plumes retrievals were detected with optical depths as high as 16. The sensitivity of the retrieval to different optical properties is examined and the radiative impact explored.
Caterina Mogno	Investigating the relationship between modeled PM2.5 concentrations and surface aerosol optical properties in the NASA GEOSCCM	Surface fine particulate matter concentration (PM2.5) and its chemical and optical properties are important to understand for health, air quality, and climate applications. Better understanding of the relationship between surface particulate matter concentrations and aerosol optical properties is essential to take advantage of the spatial coverage from satellite observations in characterizing the aerosol load and to ensure confidence in aerosol models. Here we evaluate the modeled relationship in PM2.5 and surface aerosol optical properties for the period 2000-2018, combining simulations performed with the NASA Goddard Earth Observing System Chemistry Climate Model (GEOSCCM) and ground-based observations. GEOSCCM uses the Goddard Chemistry, Aerosol, Radiation, and Transport (GOCART) aerosol mechanism and considers dust, sea salt, sulfate, nitrate, and carbonaceous aerosol species. We compare the GEOSCCM global simulated PM2.5 and its component species with observations from ground-based networks. Modeled surface aerosol optical properties, such as absorption and scattering coefficients, are compared with ground-based observations from Global Atmosphere Watch (GAW) and contributing networks. We then link and interpret the model performance in simulating PM2.5 with its ability to reproduce surface aerosol optical properties. This comparison offers insights into the GEOSCCM strengths and weaknesses in simulating PM2.5, surface aerosols optical properties, and their relationship, serving as a benchmark for future model developments and improvements to projecting future surface aerosol loading and composition.
Christina S. McCluskey	Process-level model diagnostics from in situ observations of aerosol abundance, composition, and cloud activation	At present, in-situ observations are not utilized to their full potential for aerosol-cloud-interaction research because implementing comparisons between coarse resolution models and in-situ observations requires scientific and technical expertise in both modeling and observations. The modeling community would benefit from new diagnostics for determining model skill of the increasingly complex representations of aerosol and clouds, and the observation community would benefit from modeling exercises that contextualize findings and inform future field campaign design. For example, aerosol optical depth is often used to assess model aerosol, yet aerosol number and composition are key aerosol properties that influence aerosol impacts on clouds via their action as cloud condensation nuclei (CCN) or ice nucleating particles (INPs). As such, there is a growing need for model diagnostics that target processes, systems, or locations that are not possible to probe with satellite. In this presentation, we will highlight the use of aerosol observations from ground, ship, aircraft, and tethered balloon based aerosol observations for assessing aerosol simulated in the Community Atmosphere Model (CAM6). Instrument simulators that translate model output from the Modal Aerosol Model version 4 (MAM4) into meaningful comparison metrics were developed based on the sampling and measurement capabilities of the field instrument. Instrument simulations were "deployed" during several field campaigns that took place over the Southern Ocean and at the DOE North Slope of Alaska measurement site using a nudged configuration of the CAM6. Model aerosol diagnostics included aerosol amount (aerosol number, surface area, and size distributions), aerosol composition, CCN number concentrations and spectra, INP number concentrations, which aid in understanding model biases.

Name	Presentation title	Presentation Abstract
Ciara Donegan	Analyzing Earth system model sensitivity to shifts in shipping SO2 emissions	Previous work on the Emissions Model Intercomparison Project (Emissions-MIP) compared various models' representations of the impact of SO2 emissions' seasonality, injection height, and SO4 fraction on the Earth system, with the goal of promoting consistent representation of SO2 emissions between models. The continuation of Emissions-MIP further compares model outputs given reductions in SO2 emissions from the shipping industry, as well as changes in the global distribution of emission sources. The current phase of the project considers six Earth system models (CESM, E3SM, GISS, NorESM2, GEOS, and CAM-ATRAS) and will compare variations in their modeled emission concentrations, radiative forcings, and aerosol deposition rates given these perturbations in SO2 emissions. This study is performed using the Earth System Model Evaluation Tool (ESMValTool) and will report on preliminary results of the ongoing experiment; results thus far suggest that emission reductions cause large variations between model outputs, stressing the need for standardization of SO2 emission representation between models.
Damao Zhang	Aerosol Vertical Distributions Observed with ARM Ground-based Remote Sensing Measurements	Understanding vertical and temporal distributions of aerosols is essential for accurately quantifying aerosol radiative effects and improved process-level understanding of aerosol-cloud-precipitation-interactions. Ground-based active remote sensing measurements such as lidars provide high vertical and temporal observations of atmospheric aerosols. The current Atmospheric Radiation Measurement (ARM) user facility Raman Lidar (RL) Vertical Profiles Feature Detection and Extinction (RLPROF-FEX) Value-added Product (VAP) provides vertically-resolved information on aerosol features but is only available at several ARM observatories. Following the similar logic and flow of the RLPROF-FEX VAP, we developed a new VAP specifically for identifying aerosol features using ARM High Spectral Resolution Lidar (HSRL) or Micro-pulse Lidar (MPL) so that vertically-resolved aerosol feature information is available at each ARM observatory. We then analyze aerosol vertical distributions regarding their occurrences, lidar scattering ratios, backscattering coefficients, and depolarization ratios using multiple years of lidar data at multiple ARM observatories. We compare statistical differences of aerosol vertical distributions at different ARM observatories and their seasonal variations. Finally, we outline our future plan of retrieving vertically-resolved aerosol microphysical properties using combined HSRL and RL backscatter and extinction profiles.
Daniel Grosvenor	Evaluating aerosols in the next UK Earth System Model	Aerosol forcing uncertainty is one of the major drivers of climate change projection uncertainty by climate models. One reason for this uncertainty is a lack of comprehensive evaluation of the representation of aerosols in climate models using observations that goes beyond comparisons to aerosol optical depth measurements. Here we describe the evaluation of aerosols during the development phase of the upcoming version of the CMIP7 UK Earth System Model using ground-based aerosol size distribution data that has been compiled into a model-ready database within the GASSP project. For this we utilize the prototype of an aerosol evaluation toolkit for models that will eventually provide a community tool to facilitate a straightforward comparison of model data to aerosol observations of various types. The aerosol size distributions compare well for more polluted regions such as Beijing and the Pearl Delta River regions of China, and also over many remote regions (the Canadian Arctic, Amazonian rainforest, Malaysian Borneo rainforest). However, in some remote regions, such as Whistler and Egbert in Canada, the model produces large overestimates of number concentrations. These results are further investigated using satellite observations of aerosol optical depth and cloud droplet number concentration, and using Aeronet extinction profiles.
Daniel McCoy	Leveraging perturbed parameter ensembles to understand how aerosol-cloud-precipitation processes imprint on the global energy budget	The processes that govern aerosol-cloud-precipitation interactions (ACPIs) operate on the scale of aerosols, droplets, and clouds. However, the pathway to link these processes to global radiative forcing must ultimately go through coarse resolution global models that heavily parameterize these processes. Given the large number of non-linear processes governing ACPIs, exploring the model parameterization landscape is a challenge. Perturbed parameter ensembles (PPEs) and machine learning emulation provides one potential method to systematically explore this space and understand how processes imprint on the global energy budget. Here, we present results from a PPE hosted in the sixth Community Atmosphere Model (CAM6). The PPE is confronted with a suite of observations from satellites, to aircraft, and to surface observations. This provides both model constraint and understanding of how parameterized sub-grid processes affect global energy flux. Critically, the PPE allows exploration of causality in ACPIs and interpretation of observed covariability between aerosols, clouds, and precipitation.
Dongchul Kim	Dust source attribution to the global land and ocean regions	The major source of global dust is well established as most of them are originated from a few major source regions of North Africa, Middle East, and Asia which accounting for more than 80% of global dust emssion. Although source-receptor relationship over the source regions and downwind is simple and clear, it is difficult to attribute the source contribution when they are mixed during the inter-continental long-range transport. The present study will report the source-receptor relationships over land where affected by both local and transported dust; and remote- and ocean-regions where only contributed by long-range transport, including remote- and polar regions. A series of runs with 9 tagged regions were made to estimate the contribution of various major dust sources over the globe. In this work, we quantitively estimate (1) the impact of major sources in the global system, (2) the contribution of different source regions to various land and ocean receptor regions, (3) and we will assess the model diversity from the 7 partcipating models. Our result shows that dust-belt is the major source of global dust distribution, however models exert large diversity in source contribution over source and remote regions and in seasonality.

Name	Presentation title	Presentation Abstract
Duncan Watson-Parris	AerChemMIP2 : Deciphering the role of aerosols and chemically reactive gases in climate change	Phase 2 of the Aerosol Chemistry Model Intercomparison Project (AerChemMIP2) will focus on the quantification of the climate, atmospheric composition and air quality responses to changes in emissions of aerosols and chemically reactive gasses. Such short-lived climate forcers (SLCFs) play a fundamental role in regional and global climate change. AerChemMIP2 aims at a better understanding of the relative contributions of individual SLCF emissions to composition change, radiative forcing and the climate response from the pre-industrial to present-day as well as for projected future emission scenarios. Assessing feedbacks from natural emissions relevant to SLCFs on atmospheric composition and climate change is a key component in AerChemMIP2. The experimental protocol builds on methodological knowledge, e.g., gained through AerChemMIP, RFMIP and ScenarioMIP, which were endorsed by CMIP6. Specifically, AerChemMIP2 seeks to closely align with the CMIP7 core experimental design, namely the Diagnostic, Evaluation and Characterization of Klima (DECK), historical, and future scenario experiments. In addition to the proposal of new Earth system model experiments, AerChemMIP2 will request diagnostic output from CMIP7 core experiments to facilitate targeted analyses on the role of aerosols and chemistry in composition and climate change. This can include output from kilometer-scale climate experiments through the advancement of the next generation of global coupled atmosphere-ocean models. We hope this presentation will provide an opportunity for community feedback and discussion so we can maximize the scientific impact of these experiments.
Edward Gryspeerdt	Cloud focused diagnostics for AeroCom simulations	Cloud diagnostics are important for understanding how the indirect effect is represented in models. With the correct selection of output variables, a large number of future analyses can be performed on the output from matched PD/PI simulations. The aim here is to present an initial set of output that could be collected more regularly in AeroCom simulations. We aim to collect additional input on potential analyses that could be performed on such a pair of simulations, along with modelling groups that are interested.
Evgueni Kassianov	Ground-based spectral radiation measurements with extended wavelength range for aerosol-cloud-surface studies	Spectral radiation measurements collected by ground-based instruments with worldwide deployment have been used broadly to characterize important climate-related properties of atmospheric aerosol, clouds, and land surface. Typically, these measurements span a quite narrow spectral range (roughly 600 nm from 400 to 1000 nm) and thus provide only limited information required for improved evaluation of model predictions. Here we introduce novel ground-based measurements of total irradiance and its direct and diffuse components with spectral coverage extended to 1625 nm, effectively twice the typical span. We also demonstrate for the first time how these measurements supported by the Atmospheric Radiation Measurement (ARM) Program can be used to accurately report aerosol optical depth out to 1625 nm. Our initial demonstration involves a computationally efficient parameterization of line-by-line gas absorption corrections needed for accounting complex gas absorption spectrum in the near-infrared spectral range (around 1600 nm). Finally, we highlight expected applications of these novel measurements for advanced retrievals of aerosol, cloud, and surface properties, which are imperative in the context of evaluation and improvement of models.
Hailong Wang	New aerosol features and their coupling with atmospheric chemistry in preparing E3SM for CMIP7 and beyond	With increasing computing power, detailed physical and chemical processes representing aerosols and their interactions with other components of the climate system can be treated more explicitly and accurately in earth system models. Several advanced treatments to the representation of aerosols and cloud-aerosol interactions have been implemented in the U.S. DOE Energy Exascale Earth System Model version 1 (E3SMv1), including aerosol emissions, new aerosol particle formation, explicit aging of carbonaceous aerosol species, wet scavenging processes, ice nucleation, and deposition of light-absorbing particles to snowpack and sea ice, which have led to better simulations of aerosol spatial distributions and/or their global impacts, compared to the original model (E3SMv0/CESM1.3). The current E3SM versions (v1/v2) simulate the major aerosol species but crudely treat or even neglect some important aerosol components (e.g., nitrate, brown carbon, SOA, and stratospheric sulfate). Several science-driven model developments of new aerosol features, including nitrate aerosols, explicit SOA sources/sinks, prognostic stratospheric sulfate, and dust emissions, have been made in E3SM to better capture their roles in the Earth system. One challenge in the explicit treatment of nitrate, SOA and stratospheric sulfate is that it requires comprehensive atmospheric chemistry to represent the reactions involving precursor gases and oxidants. Two different chemistry packages have been implemented to represent the new aerosol features and their coupling with chemistry in E3SM. The E3SM aerosol development work, evaluation, and sensitivity test results, focusing on new modeling capabilities and improvements in the prediction of global aerosols, will be presented and discussed at the meeting.
Harri Kokkola	Correlations between cloud condensation nuclei and cloud droplet number concentrations in global models and observation	The susceptibility of cloud droplet number concentration (CDNC) to cloud condensation nuclei (CCN) number concentration is one of the major factors controlling aerosol indirect forcing. In this study, we investigate the sensitivity of CDNC to CCN concentrations using long-term in-situ observations from three stations (Puijo, Pallas, Zeppelin) located in Finland and the Arctic. These stations represent semi-urban, remote, and Arctic remote environments with differences in typical updraft velocity conditions as well as aerosol number concentrations. We compare the in-situ observations with four global climate models (ECHAM-M7, ECHAM-SALSA, NorESM, and UKESM). These models differ in their aerosol presentation: ECHAM-M7, NorESM, and UKESM have modal aerosol presentation, while ECHAM-SALSA has the sectional presentation. The activation parameterization is the same in all model setups. In the comparison, we use CDNC and CCN model outputs of the grid box corresponding to the location and height for each station. Additionally, we compare the updraft velocities from the models and stations when they are available. Our current observational results show a very high susceptibility of CDNC and CCN at all investigated stations. The agreement between the large-scale models and observations was very good for the Puijo and Pallas stations. However, for the Arctic station (Zeppelin), the modeled CDNC susceptibility to CCN was much lower than the observed. Moreover, at Zeppelin, CDNC exhibits very low values that are below the lower bound imposed by many global models.

Name	Presentation title	Presentation Abstract
Hui Wan	Combining physical understanding with mathematical theory to improve the numerics of process coupling in aerosol-climate models.	Sophisticated aerosol-climate models typically involve detailed representations of many dynamical, physical and chemical processes. We will use an earlier example from ECHAM-HAM and a more recent example from E3SM to demonstrate that the numerical methods used for coupling different processes in a model's time loop may end up playing a dominant role in determining the overall accuracy and characteristics of the numerical results. Combining physical understanding with budget analyses and leveraging a theoretical error analysis framework, one can obtain insights into the pros and cons of numerical coupling schemes used in current models, as well as design alternative schemes aiming at good trade-offs between numerical accuracy, computational efficiency, and software simplicity. Our efforts presented here and the community's interest in modularized process representations can be mutually beneficial.
Huisheng Bian	Observationally constrained analysis of sulfur cycle in the marine atmosphere with NASA ATom measurements and AeroCom model simulations	The sulfur cycle plays a key role in atmospheric air quality, climate, and ecosystems. In this presentation, we compare the spatial and temporal distribution of four sulfur-containing species, DMS, SO2, MSA, and SO4, that were measured during the airborne NASA Atmospheric Tomography (ATom) mission and simulated by five AeroCom-III models to analyze the budget of sulfur cycle from the models. This study focuses on remote regions over the Pacific, Atlantic, and Southern Oceans from near the ocean surface to ~12-km altitude range, and covers all four seasons. These regions provide us with highly heterogeneous natural and anthropogenic source environments, which is not usually the case for traditional continental studies. We examine the vertical and seasonal variations of these sulfur species over tropical, mid-, and high-latitude regions in both hemispheres. We identify their origins from land versus ocean and from anthropogenic versus natural sources with sensitivity studies by applying tagged tracers linking to emission types and regions. In general, the differences among model results can be greater than one-order of magnitude. Comparing with observations, simulated SO2 is generally low while SO4 is high. There are much larger DMS concentrations simulated close to the sea surface than observed, indicating that the DMS emissions may be too high from all models. Anthropogenic emissions are the dominant source (40-60% of the total amount) for atmospheric sulfate simulated at locations and times along the ATom flight tracks at almost every altitude, followed by volcanic emissions (18-32%) and oceanic sources (16-32%). Similar source contributions can also be derived at broad ocean basin and monthly scales.
Huisheng Bian	Evaluating and Improving GEOS aerosol simulations using ORACLES Measurements	Aircraft measurements from ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) have been used to evaluate and improve GEOS model aerosol simulations. This presentation focuses on our recently submitted studies on this topic. Our goal is to illustrate one way a model might be assessed and improved by measurements and to highlight the limitations of available measurements to actually constrain the underlying mechanisms. The study used ORACLES-I in-situ and remote sensing observations to examine smoke plume structure in the source and outflow regions of biomass burning in Southern Africa, using single scattering albedo (SSA) and aerosol physical/chemical/optical properties. By revealing aerosol OA and BC mass concentrations and plume ages vertically, we hypothesized a chemical or microphysical loss process exists to explain the change in aerosol absorption with plume age, and we applied a simple 6-day e-folding loss rate to the model hydrophilic biomass burning OA to mimic this process in GEOS. We also utilized the ORACLES airborne observations to better constrain the simulations of aerosol optical properties by adjusting the assumed particle size, hygroscopic growth, and absorption.
Ian Baxter	High latitude extreme poleward aerosol transport events (Aerosol Atmospheric Rivers) in E3SM and their impacts on the Arctic climate system during the MOSAiC field campaign.	The role of atmospheric aerosols is a key uncertainty in the response of the polar regions to continued anthropogenic warming as aerosols can modulate radiative fluxes directly through absorption and scattering as well as indirectly through their interactions with clouds and surface albedo. In recent years, model development and analysis has highlighted an increasing importance of aerosols in determining simulated trends in Arctic climate change over the historical period. However, despite a strong sensitivity to aerosol forcing, global climate models such as the Energy Exascale Earth System Model (E3SMv2) and Community Earth System Model (CESM2), underestimate meridional transport and concentrations of aerosols at high latitudes relative to observations and reanalysis, degrading confidence in their ability to simulate historical and future changes in polar climate. To understand the causes and implications of this underestimation, we conduct E3SMv2 simulations with winds nudged to those from the Modern Era Retrospective Reanalysis version 2 (MERRA-2) and aerosol source-region tagging. Our analysis focuses on the 2019-2020 Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition period to utilize in situ measurements from the central Arctic. We find improved agreement between MOSAiC black carbon measurements and simulated transport events when specific large-scale circulation patterns determining key transport pathways are captured. Extending the concept of atmospheric rivers to extreme aerosol transport events, we also find an important role of aerosol atmospheric rivers (AARs) in contributing to extremely high concentrations during MOSAiC and modifying radiative fluxes across the Arctic both directly and indirectly in simulations with SSP245 versus GFED wildfire emissions. We also compare AARs in the E3SMv2 to similar events simulated in E3SM-Arctic, which has regionally refined ocean and atmospheric horizontal grids poleward 45°N, to identify resolution sensitivity of the filamentary structure in extreme aerosol transport events.

Name	Presentation title	Presentation Abstract
Israel Silber	ESM Process-Oriented Evaluation Using ARM Ground-Based Measurements and the Earth Model Column Collaboratory (EMC²)	Cloud-climate feedbacks are still the most significant source of uncertainty in current climate projections. Evaluation of Earth System Models (ESM) global and single-column model (SCM) simulations using observations can inform about potential issues and model weaknesses and provide guidance for increasing the faithfulness of model representation of clouds and their interactions with aerosol, which could reduce these uncertainties. Comprehensive datasets of ground-based measurements, such as those collected by the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility, provide an unmatched sensitivity and range gate separation required to study cloud states and estimate process rates such as those occurring at and below accurately determine cloud base, a region often obscured to satellites. Because observed quantities are commonly different than model output variables, instrument simulators faithful to the examined model physics can be used to bridge this gap and facilitate direct model-observation comparisons. Here, we leverage ground-based measurements from ARM deployments and the Earth Model Column Collaboratory (EMC²) instrument simulator and subcolumn generator to evaluate the representation of aerosol-mediated cloud processes at high latitudes. We briefly examine the microphysical structure of an Antarctic mixed-phase cloud in a NASA Goddard Institute for Space Studies ModelE3 SCM simulation. We then focus on cloud base precipitation properties, which serve as strong observational constraints on ESM physics since they deconfound the product of aerosol-mediated cloud condensate sink processes from the potential influence of the atmospheric thermodynamic state between the surface and cloud base on the precipitating hydrometeor growth, evaporation, or sublimation. Using long-term observations from an ARM Arctic site at the North Slope of Alaska, we evaluate the representation of mixed-phase cloud ice precipitation properties at cloud base in free-running 9-year global ESM simulations, the output variables of which are extracted for the coordinates corresponding to the ARM Arctic site and processed with EMC2. The analysis of these simulations enables us to test the natural behavior of these models, namely, ModelE3, the NCAR Community Earth System Model Version 2 (CESM2), and the DOE Energy Exascale Earth System Model Version 1 (E3SMv1). The analysis presented here demonstrates key differences between the models and examines the agreement of model output with the observations.
James Mather	ARM User Facility Aerosol Measurements Supporting Model and Satellite Validation and Research	The US Department of Energy Atmospheric Radiation Measurement (ARM) user facility operates a network of six extensively instrumented ground-based atmospheric observatories and supporting aerial measurements. These measurements support climate process research and are ultimately intended to support the evaluation and development of earth system models. Each ARM observatory provides measurements of cloud, aerosol, precipitation, and the background atmospheric state. Aerosol measurements include both in situ sampling and lidars. In this presentation, I will provide an overview of ARM measurements including current and planned aerosol measurement capabilities along with current activities to partner with modeling and satellite programs – as well as with complementary ground-based measurement programs. In establishing these partnerships, and in engaging at this workshop, ARM is seeking to broaden and extend the impact of our measurements on climate science.
Jason Blake Cohen	Merging Satellites and In-situ Observations in an Inverse Probabilistic MIE Model and Mass-Conserving Framework to Estimate Atmospheric Column BC	Black carbon (BC) tends to be underestimated by models when compared with column observations, especially so in rapidly developing areas. While total aerosol surface concentrations have generally decreased, absorbing aerosols have not decreased at the same rate. In fact, in some areas they have increased, a finding at odds with regulations designed to improve air quality and reduce climate altering species. Observations of particle absorption from multiple satellites including MISR, OMI, TROPOMI, GEMS, and GOCI, upward looking observations of absorption from AERONET and SONET, and in-situ observations from aethalometer and particle sizers are employed in tandem. A simple mass-conserving framework is consistently applied to these large datasets, trained on a day-to-day basis throughout the length of available observations, and using multiple observations where they overlap in space and time. An inversely applied Core-Shell MIE framework is probabilistically employed using observations across the radiative spectrum to constrain the size and absorption per particle. This method is found to work very well for extreme events detection, as well as changes occurring both inter-annually and intra-annually. By conserving both particle mass and number, considering first order thermodynamics of the initial combustion conditions, and chemical aging, the rates of co-emitted species are also considered. This allows for additional information to be obtained linking back to the source types and/or processes to be obtained. Furthermore, uncertainty bounds are harmonized across the set of observations, with total uncertainty generally found to be smaller than day-to-day and grid-to-grid variability. The effectiveness of reductions in urban areas and at energy consuming industries are quantified, demonstrating both improvements and new sources or increased emissions in other areas. Attribution of UV radiation, chemistry, and atmospheric transport are considered, and biases are discussed
Jasper Kok	Derivation of a historical dust emission inventory to estimate dust radiative forcing using global aerosol models	Sedimentary records indicate that atmospheric dust has increased substantially since preindustrial times. However, global models are unable to capture this historical increase in desert dust, which hinders assessments of the effect of the historical dust increase on Earth's climate. Therefore, to enable models to account for the impacts of the historical dust increase on climate and the Earth system, we construct a globally gridded dust emission inventory spanning 1840-2000. We do so by combining 19 sedimentary records of dust deposition with observational and modeling constraints on the modern-day dust cycle. The derived inventory contains decadal variability of dust emissions as forced by the decadal variability in the deposition time series, due to which the derived emissions increase by approximately 50% from the 1850s to the 1990s. We evaluate the emission inventory and illustrate its effectiveness in enforcing a historical dust increase in ESMs by implementing it into the Community Earth System Model (CESM2.2) and conducting a long-term (1851–2000) dust cycle simulation. The simulated dust deposition is in reasonable agreement with the long-term increase in most sedimentary dust deposition records and with measured long-term trends in dust concentration at Miami and Barbados. This contrasts with CESM simulations using a mechanistic dust emission scheme and with simulations from the Coupled Model Intercomparison Project (CMIP6), which show little to no secular trends. The use of the emission inventory thus enables global models to account for radiative forcing due to the historical dust increase, including due to dust direct interactions with radiation, which our simulations estimate have produced a direct radiative forcing of −0.10 W m-2. This emission inventory is being used for a new AeroCom experiment: DUst Radiative Forcing from reconstructed dust changes since pre-industrial times (DURF).

Name	Presentation title	Presentation Abstract
Jerome Fast	Using CACTI Campaign Measurements Collected in Argentina to Evaluate Global Model Aerosol Predictions	The Cloud, Aerosol, and Complex Terrain Interactions (CACTI) field campaign was conducted over the Sierras de Cordoba range in north-central Argentina between October 2018 and April 2019 to better understand the role of atmospheric thermodynamics, topographic forcing, and aerosols on the lifecycle of convective clouds. Similar ground-based and aircraft aerosol measurements up to an altitude of ~6 km MSL were collected during CACTI. The observations suggest that aerosol properties are strongly controlled by changing synoptic meteorological conditions. The northerly low-level jet along the eastern side of the Andes frequently transports biomass and biogenic burning aerosols from the southern Amazon basin into Argentina. When the winds shift to the south, concentrations of accumulation mode aerosols decrease as concentrations of coarse dust particles originating from Patagonia increase. Accumulation mode aerosols on some days are highly correlated with carbon monoxide, suggesting the aerosols primarily originate from anthropogenic or biomass burning sources. This correlation is weak on other days, suggesting natural sources dominate. Significant decreases in accumulation mode aerosols, resulting from wet scavenging and/or changing air masses, are also associated with periods of rain. The extensive CACTI measurements provide an opportunity to evaluate the performance of global model aerosol predictions in the southern hemisphere where in situ data is sparse. The spatial and temporal variations in aerosol number, mass, size, composition, compositional mixing state, and cloud condensation nuclei (CCN) from both ground and airborne instrumentation are compared with predictions from the E3SM, MERRA-2, and CAM-Chem global models. Biases in CCN will affect the ability of models to adequately represent aerosol-cloud interactions. For E3SM, simulations with and without new treatments of nucleation and ultrafine particles are compared since the measurements indicate frequent new particle formation events at the surface and transient high concentrations of ultrafine particles aloft. MERRA-2 and CAM-Chem are often used to provide boundary conditions for regional models; therefore, biases in those models can impact the predictions of higher-resolutions simulations.
Jianyu Zheng	Thermal infrared dust optical depth and coarse-mode effective diameter over oceans retrieved from collocated MODIS and CALIOP observations	Mineral dust aerosol with a broad size range (particle diameter (Dp) from 0.001 to 100 μm) can be transported from local scales to intercontinental and further hemispherical scales, exerting far-reaching impacts on the climate system. The quantification of the spatiotemporal variation of dust physicochemical properties, such as dust loading, optically represented by dust aerosol optical depth (DAOD) and dust particle size distribution, especially the coarse mode (Dp > 1 μm) remains uncertain. In the presentation, I will introduce our newly developed algorithm to simultaneously retrieve dust aerosol optical depth at 10 μm (DAOD10μm) and the coarse-mode dust effective diameter (Deff) over global oceans based on the collocated Moderate Resolution Imaging Spectroradiometer (MODIS) thermal infrared (TIR) observations and dust vertical profiles from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). Afterwards, I will present the validation of the Deff retrieval assessing by comparing the dust lognormal volume particle size distribution (PSD) corresponding to retrieved Deff with the in-situ measured dust PSDs from the AER-D, SAMUM-2 and SALTRACE field campaigns through case studies. The new DAOD10μm retrievals were evaluated through comparisons with the collocated DAOD10.6μm retrieved from the combined Imaging Infrared Radiometer (IIR) and CALIOP observations from our previous study (Zheng et al. 2022) and the two independent Infrared Atmospheric Sounding Interferometer (IASI) products. Lastly, I will show the climatological analysis of coarse mode dust Deff over global oceans, focusing on North Atlantic, Indian Ocean and North Pacific. To our best knowledge, this study is the first to retrieve both DAOD and coarse-mode dust particle size over global oceans for multiple years. This long-term (from 2007 to 2018) retrieval dataset provides insightful information for evaluating dust long-wave radiative effects and coarse mode dust particle size in models, and is publicly available along with the publication.
Jie Gao	Aerosol Effects on Heating in the Asian Monsoon Tropopause Layer	The Asian tropopause aerosol layer (ATAL) emerges annually as an accumulation of aerosols near the tropopause above the Asian summer monsoon. Although ATAL effects on surface and top-of-atmosphere (TOA) radiation budgets are well established, the magnitude and variability of ATAL effects on radiative transfer within the tropopause layer remain poorly constrained. Here, we investigate the impacts of various aerosol types and layer structures on radiative heating in the Asian monsoon tropopause layer using reanalysis products and offline radiative transfer simulations. ATAL effects on shortwave radiative heating based on different aerosol forecast and analysis products range from ~10% to ~70% and peak between 150 and 80 hPa (360–400 K potential temperature) along the southern flank of the anticyclone. Clear-sky and all-sky shortwave heating are at local minima in this vertical range, which is situated between the positive influences of monsoon-enhanced water vapor and the negative influence of the "ozone valley" in the monsoon lower stratosphere. Results from global model experiments conducted for the AeroCom Phase III Atmospheric Composition and Asian Monsoon (ACAM) experiment are used to provide additional context to these results and to further quantify aerosol effects on diabatic heating, transport timescales, and dynamical fields within the monsoon tropopause layer.
Jin-Ho Yoon	Aerosol-Induced atmospheric response through differential heating and teleconnection	Aerosol induced radiative forcing has been recognized as one of the important climate forcings. More importantly, spatial gradient of such forcing could drive atmospheric anomalous circulation depending on its location and strength. Given the fact that the most of aerosol emission sources located in the Northern Hemisphere, it is plausible to propose that hemispheric differential heating induced by aerosol could force large-scale atmospheric response. The African Sahel experienced a remarkable drought during the 1970s and 80s, followed by some recovery signs in the 1990s. While various factors have been considered responsible, including natural variability like the Atlantic Multidecadal Oscillation and anthropogenic factors such as aggressive land management, recent studies introduce the influence of anthropogenic aerosols from industrialized nations. These aerosols may have contributed to Sahel drought by cooling the sea surface temperature (SST) over the North Atlantic Ocean, leading to a southward shift of the Intertropical Convergence Zone (ITCZ) and a weakened African monsoon. This abstract explores the role of aerosol-induced atmospheric response through differential heating and teleconnection in the context of Sahel's climate variability. Utilizing the latest climate model simulations including newly developed GRIMs-CCM, we present evidence that both the drought and recovery phases in Sahel could be linked to anthropogenic aerosols. The cooling effect induced by aerosols creates differential heating patterns in the atmosphere, leading to changes in teleconnection patterns that can directly impact rainfall variability over large land areas like Sahel.

Name	Presentation title	Presentation Abstract
Johannes Muelmenstaedt	Does the droplet number–liquid water path 'inverted v' tell us what we think it does? Causal and confounding mechanisms for observational constraints on ERFaci adjustments	General circulation models (GCMs) estimate stronger effective radiative forcing by aerosol–cloud interactions (ERFaci) than other lines of evidence. The discrepancy is thought to stem in part from GCMs' inability to represent the turbulence–microphysics interactions in cloud-top entrainment that lead to a reduction in liquid water in stratocumulus-type clouds in response to an anthropogenic increase in aerosols. In the real atmosphere, precipitation suppression at low droplet number and enhanced cloud-top entrainment at high droplet number compete with each other, leading to an 'inverted v' shape of liquid water path plotted against droplet number. Enhanced entrainment is thought to be the dominant adjustment mechanism for liquid water path in the real atmosphere, weakening the overall ERFaci. We show that the latest generation of GCMs includes models that produce a negative correlation between present-day cloud droplet number and liquid water path, a key piece of observational evidence supporting liquid water path reduction by anthropogenic aerosols and one that earlier-generation GCMs could not reproduce. However, even in the GCMs with a negative correlation, the increase in anthropogenic aerosols from preindustrial to present-day values still leads to an increase in liquid water path. This adds to the evidence that correlations in the present-day climate are not necessarily causal. Sources of confounding are investigated to explain the noncausal correlation between liquid water path and droplet number. These results are a reminder that assessments of climate parameters based on multiple lines of evidence must carefully consider the complementary strengths of different lines when the lines are in disagreement. We discuss how an AeroCom experiment could be designed to address the multiscale nature of the ERFaci problem by combining the representativeness of global models (GCMs and global storm-resolving models) with the cloud process fidelity of LES.
John Shilling /James Mather	Overview of Atmospheric Radiation Measurement (ARM) Aerosol Measurements	The U.S. Department of Energy’s Atmospheric Radiation Measurement (ARM) Climate Research Facility operates a large suite of aerosol measurement instrumentation at multiple fixed and mobile sites around the world. Data from several sites extends for several decades, providing unique, long-term datasets. The ARM instruments measure a host of aerosol properties that are useful for validating climate models and remote sensing measurements including: aerosol chemical composition, aerosol size distributions, CCN concentrations at multiple supersaturations, in-situ aerosol optical properties, and aerosol optical depth. In addition, data from multiple instruments is often combined to produce Value Added Products (VAPS) that reduce the amount of data processing ARM users need to conduct on their own. For example, the merged size distribution VAP merges the size measurements from several instruments into a single combined size distribution. Here, we provide an overview of several aerosol measurement datasets that should be of interest to the modeling and satellite communities.
Jonathon Wright	Summary of the SPARC Reanalysis Intercomparison Project Phase 1 and Plans for Phase 2: Chemical & Aerosol Reanalyses, Tropospheric Circulation, Extreme Events, and More	Reanalysis datasets are widely used to understand atmospheric processes, yet different reanalyses may give very different results for the same diagnostics. The Stratosphere-troposphere Processes And their Role in Climate (SPARC) Reanalysis Intercomparison Project (S-RIP, https://s-rip.github.io) is a coordinated activity to compare key diagnostics among available reanalyses, identify differences among reanalyses and their underlying causes, provide guidance on appropriate usage of reanalyses in scientific studies, and contribute to future improvements in the reanalysis products via collaborations with reanalysis centers and data users. S-RIP Phase 1 (completed in early 2022) focused primarily on the upper troposphere through the middle atmosphere and processes linking these regions to the troposphere and surface. We look forward to broadening our efforts in Phase 2 (S-RIP2), with new foci including studies of tropospheric circulation, extreme weather events, and their links to the stratosphere, and focusing on evaluation of chemical reanalyses, both those with a stratosphere / upper troposphere focus and those that focus on air quality applications. This presentation will provide a summary of Phase 1 results and discussion of future directions for S-RIP2, emphasizing plans for aerosol reanalysis evaluation and capacity building for Early Career Scientists.
Julia Shuvalova	The main cloud characteristics influencing variations of solar irradiance at ground according to the ICON model, CLOUDNET and BSRN observations	We analyzed the results of ICON numerical weather prediction model with the two-moment microphysical scheme and ecRad radiative scheme using Cloudnet ground-based observations (https://cloudnet.fmi.fi) at the Lindenberg, Juelich and Munich sites, data of MODIS spectroradiometer (https://ladsweb.modaps.eosdis.nasa.gov, Collection 6 Level 2) and BSRN high-quality observations in Lindenberg Observatory. The default number concentration of cloud condensation nuclei (CCN) and CCN equal to 1700 cm-3 (as a characteristic of continental polluted clouds) were used. To estimate the background CCN value over the modeling region, we retrieved CCN number concentrations at the cloud base using the method (McComiskey et al., 2009) with MODIS 1-km resolution data. We found an underestimation of simulated grid-scale liquid water path relative to Cloudnet observations due to the specificity of cloud droplet nucleation and saturation adjustment schemes. The growth of CCN led to an increase of cloud droplets number concentration by an average of 94±20 cm-3 (65%) and the consequent increase of large-scale liquid water path by 118±2 g/m2 (40%). This led to a decrease in solar irradiance by an average of 9 W/m2 (12%) in overcast conditions. The obtained CCN effects contribute to reducing errors in the liquid water path prediction and solar irradiance at ground. We found a sufficient accuracy of cloud optical thickness forecast using SOCRATES, when the liquid water path is predicted accurately. However, the solar irradiance is on average overestimated compared to the BSRN observations. We showed that global irradiance values are more sensitive to the forecast of the direct to global solar irradiance ratio than to the liquid water path and cloud fraction forecast. A successful prediction of direct to global solar irradiance ratio (as the characteristic clouds spatial inhomogeneity) significantly improves the forecast of solar irradiance. The research was supported by the grant of Ministry of Science and Higher Education of the Russian Federation (project number 075–15–2021–574). The revision of the ICON microphysical scheme and the use of the Model Evaluation Tool verification system is carried out as part of the Roshydromet Research work AAAAA20-120021490079-3.

Name	Presentation title	Presentation Abstract
Kai Zhang	Impact of new particle formation on the anthropogenic aerosol forcing estimate in E3SM	New particle formation (aerosol nucleation) happens frequently in the troposphere. It has a large impact on the aerosol lifecycle and can substantially change the number concentrations of cloud condensation nuclei (CCN) and ice-nucleating particles. Consequently, it may significantly affect the cloud properties and the associated precipitation processes. Here we use a global atmospheric model to investigate the impact of various new particle formation mechanisms on warm and cold cloud processes and the anthropogenic aerosol forcing estimate. The model we use is the atmosphere component of the Energy Exascale Earth System Model (E3SM), with a revised Modal Aerosol Module that has a nucleation mode to better represent the evolution of newly formed particles. Results show that both the boundary layer nucleation and free-troposphere binary nucleation have a large influence on the CCN number concentration and liquid cloud formation. In addition, the free-troposphere nucleation greatly changes the number concentration of sulfate solution droplets that promote the homogeneous ice nucleation in cirrus clouds. We find the two nucleation mechanisms have very different (opposite sign in some regions) impacts on the estimated anthropogenic aerosol effect. This suggests it's important to improve/constrain the representation of new particle formation and its interaction with both warm and cold cloud processes in global aerosol-climate models.
Kostas Tsigaridis	The future chemistry and climate impacts of large, fully-reusable methane-fueled rockets	Rocket launches have clear local impacts on atmospheric composition, and the number of launches to Low Earth Orbit (LEO) from space agencies and commercial space activities are projected to greatly increase over the next few decades. The launch industry is moving toward a future dominated by methane fuel and reusable first and second stages. Accordingly, a better understanding of the broader impacts on stratospheric chemistry and climate under plausible frequency and technological scenarios are essential to fully appreciate their potential effects. Depending on the level of expansion of space exploration, the rate of launches is projected to significantly increase and is expected to include heavy launch vehicles with recoverable stages. Together with launch technology experts, we developed a discrete set of plausible future scenarios of launch-related emissions from a range of feasible rocket technologies, including their frequency, regional distribution, and vertical emission profiles, using realistic altitude-dependent simulations of rocket combustion. Emission profiles include BC, NOx (rocket combustion and reentry heating), CO, water vapor, with BC being by far the most important contributor on rocket fuel burning climate impacts. Particular attention was given to the type of fuel that will likely dominate space launches in the future, liquefied natural gas (LNG), which is also much cleaner in terms of BC emissions from the fuels that dominate present-day launches. Using the NASA GISS Earth system model ModelE, we performed future simulations (year 2050 following SSP2-4.5) using realistic emissions for different launch vehicles and plausible number of launches per year for a future that includes large satellite constellations and interplanetary exploration. We will present a large number of simulations under plausible future climate backgrounds, with updated emissions that correspond to future fuel types and a greatly increased launch rate per year. The goal is to understand how chemistry and climate are impacted by not only the emissions themselves, but also by the change in technology towards cleaner alternatives with less BC emissions, which is very absorbing in the shortwave, resulting in warming of the atmosphere where it is abundant. Although the cleaner LNG fuel emits much less BC than currently used kerosene, our simulations show that the significant increase in launch rate still results in important impacts from BC emissions. We will focus on the emissions of individual species, in particular BC, from the launch vehicle (ascent and stage two descent) and their impact on atmospheric composition and climate, both individually but also together, to study feedbacks involved with the non-linear chemistry; the role of the different background atmosphere (present-day vs. future) in any climate effect; the climate impact of the less black carbon-emitting LNG fuel compared to present-day fuels.
Laura Fierce	Quantifying structural error in aerosol properties from reduced representation of particle distributions	Aerosol effects on clouds and radiation are the dominant contribution to uncertainty in radiative forcing relative to the pre-industrial atmosphere. While previous studies have assessed the impact of parametric uncertainty on modeled forcing, structural errors from the numerical representation of particle distributions have not been well quantified. Here we present a framework for quantifying error in aerosol size distributions and cloud condensation nuclei activity, using the widely used 4-mode version of the Modal Aerosol Module as an example. Model predictions from the reduced aerosol scheme are evaluated against the Particle Monte Carlo Model for Simulating Aerosol Interactions and Chemistry, a benchmark model that tracks the evolution of individual particles. We show that size distributions from the Modal Aerosol Module diverge from the benchmark model after only a few hours of aging by condensation and coagulation in polluted conditions, which leads to large errors in modeled cloud condensation nuclei concentrations. We find that differences between the Modal Aerosol Model and the particle-resolved model are largest under polluted conditions, where the size distribution evolves rapidly though aging by condensation of semi-volatile substances and coagulation among particles. These findings suggest that structural error in modeled aerosol properties contribute to the large inter-model variability in aerosol radiative forcing.
Leighton Regayre	Aerosol evaluation must account for model-observation uncertainties	Model-observation comparisons are subject to multiple sources of uncertainty including a) observation error, b) interannual variability, c) missing processes or aerosol sources, d) model parameter tuning errors, and e) spatial and temporal representation errors. These model-observation comparison uncertainties must be accounted for when comparing climate model output to multiple observation types. Here, we compare a wide range of UK Earth System Model (UKESM) output from multi-year and nudged simulations, with multiple structural code changes, to the Global Aerosol Synthesis and Science Project (GASSP) aerosol dataset of aerosol measurements (from stations and ship campaigns). We identify strategies for aerosol evaluation in models that accounts for these sources of model-observational uncertainty. This analysis informs the development of an aerosol evaluation toolkit for wider use within the AeroCom community.

Name	Presentation title	Presentation Abstract
Li Pei	Three-dimensional aerosol reconstruction by combined active and passive satellites	Three-dimensional aerosol reconstruction by combined active and passive satellites Pei Li1, Yong Xue1,2* 1 School of Environment and Spatial Informatics, China University of Mining and Technology, Xuzhou, Jiangsu Province, 221116, China 2 School of Electronics, Computing and Mathematics, College of Engineering and Technology, University of Derby, Kedleston Road, Derby DE22 1GB, UK Abstract: Quantification of the vertical distribution of atmospheric aerosols is critical in the context of radiative forcing at the Earth's surface, atmospheric circulation, and climate modeling. However, passive remote sensing measurements have so far provided limited information on aerosol extinction profiles. Active remote sensing measurements can only provide a minimum cross-section of the atmosphere on the ground track of a satellite, which makes it difficult to provide a complete characterization of the three-dimensional aerosol structure on global or regional scales. In this paper, a scene construction algorithm developed for the EarthCARE cloud 3D reconstruction task is improved and a 3D aerosol field in China is constructed. First, a cost function is constructed from spectral radiance as well as surface reflectance to filter out points with similar radiance and reflectance. Second, a distance-dependent weighting scheme is used instead of a nearest neighbor scheme to find matches (donor-recipient.) among similar points. Finally, the donor columns observed by CALIPSO are assigned to the recipient pixels in the MODIS image. The experimental results show that the improved algorithm can construct the aerosol three-dimensional structure well. The reconstruction results are basically consistent with the assimilation products as well as other studies, and the reconstructed profiles suffer from a relative error of about 20-30% compared with the ground-based LiDAR site measurements. Keywords: Three-dimensional aerosol structure, active and passive satellites, radiation, surface reflectance
Lucia Mona / Nikos Papagiannopoulus	Aerosol typing: updates from European and Italian initiatives	
Malcolm Maas	Combining Earth System Modeling and Machine Learning to Investigate Volcanic Sulfate Deposition in Polar Ice Cores	Volcanic eruptions emit large amounts of sulfur dioxide (SO2), water, and other chemicals into the atmosphere, both in the troposphere and the stratosphere. Most of the SO2 is converted to sulfate aerosol, which is eventually deposited following long-range transport. The deposits from large eruptions are potentially detectable in ice cores, but there are many cases in which sulfate layers have not been linked to their source volcanoes. As volcanoes can act as significant shocks to the global climate system, we are interested in locating these eruptions in order to increase understanding of the volcanic record. To narrow down the search, we performed 140 simulations of volcanic eruptions using the GISS ModelE Earth system model. We varied the latitude, longitude, Julian day, plume top, plume bottom, and injected SO2 and H2O amounts using a Latin hypercube sampling approach, and analyzed correlations between these parameters and sulfate depositions at ice core sites in Antarctica and Greenland. Using machine learning and parameter estimation, we generated probability distributions and maximum likelihood estimates for the parameters given sulfate deposition data, which can predict latitude with some skill. We find that the volcano latitude and SO2 content are best correlated with sulfate depositions at each pole, while longitude, Julian day, and H2O have small or insignificant effects. Plume altitude and thickness are important because they determine how much of the SO2 is injected into the stratosphere, which has implications for sulfur transport and lifetimes.
ManishKumar Shrivastava	New SOA Treatments Within the Energy Exascale Earth System Model (E3SM): Strong Production and Sinks Govern Atmospheric SOA Distributions and Radiative Forcing	Secondary organic aerosols (SOA) are large contributors to fine particle mass loading and number concentration and interact with clouds and radiation. Several processes affect the formation, chemical transformation, and removal of SOA in the atmosphere. For computational efficiency, global models use simplified SOA treatments, which often do not capture the dynamics of SOA formation. Here we test more complex SOA treatments within the global Energy Exascale Earth System Model (E3SM) to investigate how simulated SOA spatial distributions respond to some of the important but uncertain processes affecting SOA formation, removal, and lifetime. We evaluate model predictions with a suite of surface, aircraft, and satellite observations that span the globe and the full troposphere. Simulations indicate that both a strong production (achieved here by multigenerational aging of SOA precursors that includes moderate functionalization) and a strong sink of SOA (especially in the middle upper troposphere, achieved here by adding particle-phase photolysis) are needed to reproduce the vertical distribution of organic aerosol (OA) measured during several aircraft field campaigns; without this sink, the simulated middle upper tropospheric OA is too large. Our results show that variations in SOA chemistry formulations change SOA wet removal lifetime by a factor of 3 due to changes in horizontal and vertical distributions of SOA. In all the SOA chemistry formulations tested here, an efficient chemical sink, that is, particle-phase photolysis, was needed to reproduce the aircraft measurements of OA at high altitudes. Globally, SOA removal rates by photolysis are equal to the wet removal sink, and photolysis decreases SOA lifetimes from 10 to ~3 days. A recent review of multiple field studies found no increase in net OA formation over and downwind biomass burning regions, so we also tested an alternative, empirical SOA treatment that increases primary organic aerosol (POA) emissions near source region and converts POA to SOA with an aging time scale of 1 day. Although this empirical treatment performs surprisingly well in simulating OA loadings near the surface, it overestimates OA loadings in the middle and upper troposphere compared to aircraft measurements, likely due to strong convective transport to high altitudes where wet removal is weak. The default improved model formulation (multigenerational aging with moderate fragmentation and photolysis) performs much better than the empirical treatment in these regions. Differences in SOA treatments greatly affect the SOA direct radiative effect, which ranges from −0.65 (moderate fragmentation and photolysis) to −2 W m−2 (moderate fragmentation without photolysis). Notably, most SOA formulations predict similar global indirect forcing of SOA calculated as the difference in cloud forcing between present-day and preindustrial simulations.

Name	Presentation title	Presentation Abstract
ManishKumar Shrivastava	Shift in Peaks of PAH-Associated Health Risks From East Asia to South Asia and Africa in the Future	Lung cancer risk from exposure to ambient polycyclic aromatic hydrocarbons (PAHs) is expected to change significantly by 2050 compared to 2008 due to changes in climate and emissions. Integrating a global atmospheric chemistry model, a lung cancer risk model, and plausible future emissions trajectories of PAHs, we assess how global PAHs and their associated lung cancer risk will likely change in the future. Benzo(a)pyrene (BaP) is used as an indicator of cancer risk from PAH mixtures. From 2008 to 2050, the population-weighted global average BaP concentrations under all RCPs consistently exceeded the WHO-recommended limits, primarily attributed to residential biofuel use. Peaks in PAH-associated incremental lifetime cancer risk shift from East Asia (4 × 10−5) in 2008 to South Asia (mostly India, 2–4 × 10−5) and Africa (1–2 × 10−5) by 2050. In the developing regions of Africa and South Asia, PAH-associated lung cancer risk increased by 30–64% from 2008 to 2050, due to increasing residential energy demand in households for cooking, heating, and lighting, the continued use of traditional biomass use, increases in agricultural waste burning, and forest fires, accompanied by rapid population growth in these regions. Due to more stringent air quality policies in developed countries, their PAH lung cancer risk substantially decreased by ~80% from 2008 to 2050. Climate change is likely to have minor effects on PAH lung cancer risk compared to the impact of emissions. Future policies, therefore, need to consider efficient combustion technologies that reduce air pollutant emissions, including incomplete combustion products such as PAH.
Marcin Witek	Towards better MISR aerosol retrievals over land: An ensemble approach	Multiangle Imaging SpectroRadiometer (MISR) multi-wavelength and multi-angle observations offer a unique capability for retrieving atmospheric aerosols over most surface types, including land. The current MISR land algorithm combines the benefits of two powerful approaches: (1) the heterogeneous surface algorithm (HET) that makes use of surface contrasts and empirical orthogonal functions to represent the surface bidirectional reflectance factors (BRFs), and (2) the homogeneous surface algorithm (HOMOG) that applies spectral and angular invariance constraints to the surface BRFs. HET works best at higher aerosol loadings, whereas HOMOG is more suitable in low-AOD conditions, but together the two algorithms converge to an optimal solution that fits best in most scenarios but shows deficiencies in certain areas or in extreme cases. Here we report on a prototype, ensemble based, MISR aerosol retrieval algorithm over land that alleviates most of the deficiencies of the current operational approach. The prototype algorithm improves aerosol retrievals in both the low- and high-AOD regimes, as measured by comparisons against ground-based AERONET observations. The spatial consistency and accuracy of retrieved aerosol optical properties is also investigated. The new approach over land is also consistent with the MISR retrieval methodology over dark water.
Marcin Witek/Robert Nelson	Expanding the coverage of MISR aerosol retrievals over shallow, turbid, and eutrophic waters	Shallow and coastal waters are often rich in nutrients (eutrophic) and biologically productive, turbid from runoff, and located where the atmosphere above can be more aerosol-laden than over open ocean waters due to proximity to aerosol sources on land. Although the NASA Earth Observing System's Multi-angle Imaging SpectroRadiometer (MISR) on board the Terra satellite has been monitoring global aerosols for over 23 years, the current operational retrieval algorithm (V23) is not applied over waters less than 50 m in depth or within 5 km of land, designated as "shallow water." This is due to the simplicity of the Dark Water algorithm, applied operationally over deep waters, which assumes the surface is essentially black in the primarily used red and near-infrared spectral bands. In this work, we describe the implementation and validation of a "Shallow Water" aerosol retrieval algorithm for MISR, which takes advantage of all four available spectral bands and includes a Lambertian surface reflectivity term to account for water-leaving radiance. This algorithm compares well to independent, surface-based observations and demonstrates better performance over shallow waters than the operational Dark Water retrieval algorithm. Globally, aerosol retrievals over shallow waters increase the total number of MISR over-water measurements by more than 7%, including new retrievals made over some of the most biologically productive parts of the ocean.
Mariya Petrenko	Constraining Model Biomass Burning Source Strength and Injection Height Using Satellite Observations Project Update	A key contribution of the joint AeroCom and AeroSat communities is the investigation of ways to constrain models with satellite measurements. The Biomass Burning (BB) experiments aim to use aerosol optical depth (AOD) snapshots from the MODerate resolution Imaging Spectroradiometers (MODIS) and plume-height retrievals from the Multi-angle Imaging SpectroRadiometer (MISR) to constrain model biomass burning source strength and injection height, respectively. We estimate source strength by matching forward-simulated plume aerosol optical depth (AOD) from models with MODIS AOD. When applied to a single model consistently, the technique works best for large, isolated plumes common in boreal forest, and tends to fail where plume AOD is low and/or background AOD, distinct from the specific source of interest, is high. However, when applying the approach to multiple models, the diversity of model assumptions other than BB source strength, such as OA/OC ratio at injection, BB aerosol mass extinction efficiency, and even the fraction of BB aerosol assigned to OA, BC, and other species, makes it difficult to draw consistent conclusions about source strength in particular. Injection height is obtained from MISR stereo imagery, which makes it possible to map plume elevation and estimate the associated motion vectors at plume altitude near-source, where contrast features in the plume can be identified in the multi-angle views. A current limitation of injection-height mapping is the relatively narrow MISR swath width (~380 km) and 10:30 AM equator crossing time on the day side of Earth. However, upcoming missions, as well as advanced imagers on geostationary platforms, promise to greatly expand the spatial and temporal range over which this technique can be applied. This presentation will summarize the current status of the AeroCom/AeroSat BB source strength and injection height experiments.

Name	Presentation title	Presentation Abstract
Marta Luffarelli	Combined AOT/COT product from satellite observations	Aerosol-cloud interactions continue to largely contribute to the total uncertainty in climate models. However, the area between pure clear-sky and pure cloud is often disregarded by both aerosol and cloud retrieval algorithms, resulting in up to 20% of lost pixels (Schwarz et al., 2017). Extending the retrieval from satellites in this transition area could address the issue of lost pixels and provide global coverage and large-scale observations of aerosol-cloud mutual interactions. This talk will present the analysis of the potential application of the combined AOT/COT product obtained with the CISAR algorithm (Govaerts and Luffarelli, 2018, Luffarelli and Govaerts, 2019) applied by combining SEVIRI observations obtained onboard MSG1 and MSG4. This innovative approach allows continuity between aerosols and clouds, removing the presence of lost pixels while extending the aerosol retrieval in the vicinity and within thin clouds. The CISAR algorithm derives the optical thickness associated with the selected aerosol or cloud classes (Luffarelli et al., 2022), from which it is possible to derive, among others, the mean aerosol and cloud radius. Thanks to the availability of simultaneous retrieval of aerosols and clouds within the same pixel, it is thus possible to observe both the reduction in water cloud droplet size at increasing Fine Mode (FM) AOT (first indirect effect - Twomey, 1974) and the aerosol swelling due to the increased humidity in the area surrounding clouds (Quaas et al., 2010). CISAR provides the spectral surface downward fluxes alongside the AOT and the COT. The impact of the total OD on the amount of solar radiation reaching the surface is also discussed, particularly during the extreme Godzilla dust storm in June 2020.
Matthew Christensen	Quantifying the Impact of Aerosols on Clouds in E3SM: Insights from a Lagrangian Framework	An increase in aerosol concentration has been shown to suppress rainfall and increase the abundance of droplets in clouds passing over Graciosa Island in the Azores. Cloud drops remain affected by elevated concentrations of aerosols for several days when tracked in over 1,500 trajectories across thousands of kilometers over the Atlantic Ocean. Simulations of the Twomey effect from the U.S. Department of Energy's Energy Exascale Earth System Model (E3SM) version 1 are within 30% of the satellite and Atmosphere Radiation Measurement (ARM) observations. However, the mean cloud droplet concentration in E3SMv1 is more than 2–3 times larger than in the observations. E3SM skillfully represents the aerosol perturbations on cloud properties over the trajectories. However, the adjustments in liquid water path and cloud fraction are positive when using a least-squares fit regression model, as opposed to negative when using the present-day minus pre-industrial aerosol emissions. Despite modifications made to autoconversion and accretion model parameters that control the warm-rain process, these differences remain in the trajectories. It is unlikely that tuning these parameters alone will produce the desired aerosol susceptibilities in E3SMv1.
Mian Chin	Two-decadal trends and interannual variability of CO and aerosols in the UTLS and their connections to surface emissions, convective transport efficiency, and Asian summer monsoon dynamics - Report of AeroCom experiment	We report a new analysis on the interannual variability and two-decadal trends of CO and aerosols in the UTLS from 9 global models participating in the AeroCom UTLS/ACAM experiments. Here, we will show (1) interannual variabilities of a) Asian summer monsoon convective transport efficiency (CTE) for lifting the surface pollutants to the upper troposphere and b) Asian summer monsoon anticyclone (ASMA) strength in the UT for spread the surface-generated pollutants to global atmosphere, and (2) two-decadal trends of CO and aerosols in the UT and their connections to the surface emission, climate variability, and ASM dynamics.
Michael Schulz	Progress to build a GeneralIzed Aerosol / Chemistry iNTerface (GIANT)	The GIANT initiative by Hodzic et al. (see presentation at AGU 2022) promotes a more flexible aerosol interface, in order to be able to exchange aerosol modules in between host models. The work on this has been slowly evolving since last years AeroCom workshop. Most progress has been made in assembling the challenges and approaches in the different groups interested. For the CAM model, three different aerosol modules are being refactored, testing how modular aerosol code can be. Work in E3SM, CESM and NorESM will be reported on, so that further discussions on more joint efforts can be undertaken during the AeroCom workshop.
Minghuai Wang	Improving BC mixing state and CCN activity representation with machine learning in the Community Atmosphere Model Version 6 (CAM6)	
Mingxuan Wu	Evaluation of nitrate aerosols in E3SM and comparisons with CESM and AeroCom III models	Nitrate aerosol plays an important role in regional air quality as well as the Earth's climate system. However, it is not well represented or even neglected in many global climate models. In this study, we implement the Model for Simulating Aerosol Interactions and Chemistry (MOSAIC) module in the U.S. DOE Energy Exascale Earth System Model version 2 (E3SMv2), which is coupled with the Model for Ozone and Related chemical Tracers (MOZART) gas chemistry and the four-mode version of the Modal Aerosol Module (MAM4), to simulate nitrate aerosol and its radiative effects. We also examine the sensitivity of simulated nitrate aerosol to the treatment of gaseous HNO3 transfer to/from interstitial particles associated with different accommodation coefficients for HNO3 on dust and non-dust particles. The simulated aerosol concentrations are evaluated against ground-based (e.g., CASTNET, EMEP, EANET) and aircraft observations (e.g., ARCTAS, INTEXB) and compared with results from the NCAR Community Earth System Model version 2 (CESM2) with a similar treatment of nitrate aerosol but a different modeled climate and the Aerosol Comparisons between Observations and Models (AeroCom) phase III. We find that E3SMv2-MOSAIC simulates the spatiotemporal distributions of nitrate aerosol reasonably well, compared to CESM2 and AeroCom results. Modeled nitrate concentrations in E3SMv2 are in good agreement with ground and aircraft observations over oceans but have positive biases over U.S., Europe, and East Asia. Nitrate aerosol in E3SMv2-MOSAIC has a significant indirect radiative forcing of about -0.24 to -0.35 W m-2 and a relatively small direct forcing of about -0.02 to -0.05 W m-2.

Name	Presentation title	Presentation Abstract
Minseok Kim	Aerosol Data Fusion Using Maximum Likelihood Estimation and Deep Neural Network with Korean Geostationary Satellite Instruments: GEMS, AMI, and GOCI-II	As part of the Geostationary Korea Multi-Purpose Satellites (GEO-KOMPSAT; GK) mission, South Korea has launched two geostationary earth orbit satellites including GK-2A, and GK-2B. GK-2A carries a sensor named Advanced Meteorological Imager (AMI), which has spectral bands from visible to infrared for observations of weather variables. GK-2B carries two sensors. One of them is an ultraviolet-visible hyperspectral spectrometer named Geostationary Environment Monitoring Spectrometer (GEMS), and the other is a band (visible-shortwave infrared) observing ocean color imager named the 2nd-generation Geostationary Ocean Color Imager (GOCI-II). Regarding the retrieval of aerosol optical properties, each geostationary instrument has distinct characteristics derived from individual specifications. In this study, we perform data fusion of aerosol optical depth (AOD) with datasets from GEO-KOMPSAT using both statistical and deep neural network-based methods. The statistical fusion initially corrects the bias of each aerosol product by assuming a Gaussian error distribution and then employs maximum likelihood estimation (MLE) fusion, accounting for pixel-level uncertainty by weighting the root mean square error (RMSE) of each AOD product for every pixel. Meanwhile, a deep neural network (DNN) proves to be a powerful tool to consider the nonlinearity of retrieval uncertainties from various instruments. Hence, we propose a DNN-based AOD fusion approach utilizing the same input data as the statistical AOD fusion. AERONET AOD from Nov. 2021 to Oct. 2022 is used to calculate bias and uncertainties of the GEMS, AMI, and GOCI-II. This AERONET data also serves as a target for the DNN-based approach. The statistical and DNN-based fusion algorithms are applied from Nov. 2022 to Mar. 2023 and validated. Both fused AOD datasets exhibit Pearson's correlation coefficient over 0.9 and mean bias error under 0.04. The DNN-based fusion method demonstrates better performance in estimating high aerosol loading. Both fusion algorithms stabilize diurnal error variation and provides better insights into hourly aerosol evolution. The application of aerosol fusion to future geostationary satellite projects such as TEMPO and GeoXO can enable the production of high-quality global aerosol data.
Naser Mahfouz	Illuminating darkening clouds in climate models	Constraining the aerosol effective radiative forcing is important for a climate model’s fidelity in reproducing the historical temperature record as well as for more accurate future projection of climate change. Despite intense research activity in the past decades, profound uncertainties in said research areas remain, especially surrounding aerosol–cloud interactions. In this study, we present novel cloud albedo susceptibility calculations in a global climate model, E3SM. We examine what drives cloud albedo susceptibility in the model, probing possible mechanistic pathways to aid understanding and tuning. We particularly focus on darkening cloud regimes, wherein clouds' albedo decreases as the droplet number increases, and levers to increase such regimes. Finally, we assess the potential implications for our understanding of modeled and observed aerosol–cloud interactions in the observed present day as compared to those in the modeled preindustrial era.
Natalia Chubarova	Urban aerosol, its radiative and temperature effect using COSMO-ART model and measurements in a large megacity	For evaluation of urban aerosol over the Moscow megacity we used COSMO-ART model with TERRA_URB parameterization which allows taking into account the urban canopy effects at 2 km grid spacing as well as modified CAMS/ECLIPSE emissions. We obtained sensitivity of radiation and meteorological fields to various scenarios of urban emissions. Testing were fulfilled against the data of Mosecomonitoring Agency and the AERONET network dataset at the MSU Meteorological Observatory. Depending on emission rates the urban aerosol optical thickness provided negative effective radiative forcing of about 0.9-3.4 Wm-2 for weakly absorbing aerosol at TOA, while its estimates for highly absorbing aerosol on the contrary were positive (up to +2.5 Wm-2). The air temperature at 2 m decreases with the increase of both weakly and highly absorbing aerosols at different emission rates. This atmospheric cooling partially compensates for the urban heat island during daytime: the maximum temperature decrease due to aerosol reaches 0.5°C, while the temperature increase due to the TERRA_URB scheme for corresponding day-time conditions is 1.5°C. The composite maps of urban aerosol optical depth, radiative and temperature effects have revealed their localization over the central city area providing a growth in the atmospheric absorption up to 5 Wm-2. The work was supported by the Ministry of Education and Science of the Russian Federation grant No. 075-15-2021-574.
Noah Prime	A global anthropogenic emissions inventory of reactive gases and aerosols (1750 – 2022): an update to the Community Emissions Data System (CEDS)	High quality, recently updated emissions data are crucial for earth systems models to represent the impact of anthropogenic emissions on the environment and human health. The Community Emissions Data System (CEDS) is an open-source project which produces readily updateable historical emissions data sets by combining existing energy data and inventory data. CEDS reports on an updated global anthropogenic emission inventory (1750 – 2022) of aerosol (BC, OC), aerosol and ozone precursor compounds (SO2, NOx, NH3, CO, NMVOC), carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). CEDS reports annual country-total emissions for 71 sectors and 8 fuel categories and monthly gridded (.5 x .5 degree for all years, and .1 x .1 degree for recent years) emission fluxes for 8 sectors, with the option to select any combination of the 8 CEDS fuel categories. Relative to the previous release (O’Rourke et al 2020), this update extends emissions from 2019 to 2022; revises historical estimates; details aluminum, iron and steel, and non-ferrous metal productions; and updates all relevant data sources. The CEDS gridded datasets are now produced using new methodologies using point source data from NASA’s Ozone Monitoring Instrument (OMI) (Fioletov et al. 2016, Li et al. 2017) and other sources. Directly including point source data allows for improved spatial distribution of emissions, locating the world’s largest emitters at arbitrary spatial resolution, calculating co-emitted species, and more. The methodologies surrounding the gridding seasonality are also updated to address COVID anomalies and generally include more recent years. This data set is currently under development and will be released fall 2023.

Name	Presentation title	Presentation Abstract
Oleg Dubovik	The multi-instrument synergy retrievals developed based on the GRASP algorithm platform	For example, synergy multi-instrument retrieval approach was developed for aerosol and surface properties using different combinations of S-3A, S-3B, S-5p and HIMAWARI. Specifically, the following combinations were tested: OLCI/S-3A + OLCI/S-3B, OLCI/S-3A + OLCI/-3B +TROPOMI, and OLCI/S-3A + OLCI-3B +TROPOMI + HIMAWARI. For these combined retrievals the GRASP multi-pixel approach was used that allowed the retrieval to benefit from increased information content in the joint data set compared to any single retrieval. The joint data set had more comprehensive geometry of observations, wider spectral coverage (assured by TROPOMI and HIMAWARI observations) and temporal coverage of observations that especially help to distinguish fast variations of aerosol from rather stable surface reflectance over land. As a result, for combined retrieval the improvement in retrieved properties from every sensor. For example, the AOD derived from OLCI observation in joint OLCI/S-3A + OLCI/-3B +TROPOMI was more accurate than from OLCI retrieval alone. In addition, the consistency of the retrievals was a much higher in the joint approach with significantly higher the number of inverted pixels that passed quality screening has significantly increased resulting in a more accurate and more representative satellite product. Also , in the frame of recent ESA GROSAT approach new suborbital synergies have been applied for satellite and ground-based AERONET-like data. The main idea of the approach is that the joint satellite + AERONET data set provide enhanced constraints for reliable retrieval of both detailed properties of aerosol and surface reflectance. Indeed, AERONET observations have exceptional sensitivity aerosol while generally rely on the assumption about surface reflectance. In contrast, the satellite down-looking observations, especially over land, are often dominated by the contributions of the surface. Thus, once the joint satellite + AERONET data set is used in retrieval both aerosol and surface properties can be retrieved more accurately. This concept was shown to be very useful to test and optimize the aerosol model used in satellite retrieval, to verify calibration of satellite sensors, to derive accurate surface BRDF that can be used for satellite applications etc.
Pavel Litvinov	Land Surface BRDF Dataset from Sentinel-3/OLCI for Atmospheric Studies	Correct accounting for Earth land surface reflectance is crucial for different atmospheric composition retrievals from the space-borne measurements including aerosol, clouds and trace gases characterization, where atmosphere signal should be decoupled from the surface one. The optical measurements from the instruments onboard Sentinel 3, OLCI and SLSTR provide essential piece of information about atmospheric properties, as well as land and water parameters. Most of the inversion algorithms require auxiliary data in addition to the sensor's data to narrow the solution space and make the solution unique and sufficiently stable. In the frame of EUMETSAT Land Surface Reflectance (LSR) Sentinel-3 the surface gapless BRDF product will be created to support atmospheric composition processors of Copernicus S3 optical sensors. Here we describe the main approach for generation of Sentinel-3 LSR dataset, the surface characteristics of the product, and present first validation results of the LSR project.
Peng Xian	Intercomparison of Aerosol Optical Depths and surface particulate matter concentration from four reanalyses and their multi-reanalysis-consensus for climate studies	The emergence of multiple aerosol reanalyses in recent years has facilitated a more comprehensive and systematic evaluation of Aerosol Optical Depth (AOD) trends and attribution over multi-decadal timescales. Notable aerosol reanalyses currently available include the Navy Aerosol Analysis and Prediction System reanalysis (NAAPS-RA; Lynch et al., 2016) developed at the U.S. Naval Research Laboratory; the NASA Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2; Randles et al., 2017); the Japanese Reanalysis for Aerosol (JRAero) (Yumimoto et al., 2017) developed at the Japan Meteorological Agency (JMA); and the Copernicus Atmosphere Monitoring Service ReAnalysis (CAMSRA; Inness et al., 2019) from Copernicus/ECMWF. These aerosol reanalyses have operational aerosol forecasting counterparts and yield diverse solutions based on differences in underlying meteorology models, aerosol sources, sinks, microphysics, and chemistry. The data assimilation systems used to generate these reanalyses also have important differences in assimilation methods, and treatment of AOD observations including quality control, bias correction, aggregation, and sampling. This study presents the results of a basic verification of these four reanalyses in monthly AOD properties and surface PM concentrations versus AOD retrievals from AERONET and MODIS retrievals and surface PM observations from OpenAQ, and identifies regions where models diverge or perform poorly. To ensure consistency across the globe, a multi-reanalysis-consensus (MRC) approach was developed similar to the International Cooperative for Aerosol Prediction Multi-Model Ensemble (ICAP-MME). While the MRC does not consistently rank first among the reanalyses for individual regions, it performs well by ranking first or second globally, making it a suitable candidate for climate studies that require robust and consistent assessments. This study discusses the regional strength of each individual reanalysis and common challenges in simulating AOD and surface PMs.
Peter North	New products of global aerosol for SLSTR and (A)ATSR (1995 - 2023)	We present new products of global atmospheric aerosol from Copernicus and ESA satellite missions intended to provide climate-quality, long-term datasets using the ATSR/SLSTR family of instruments. The parameters retrieved include aerosol optical depth (AOD), fine mode fraction, dust AOD, Angstrom exponent and retrieval uncertainty. The method for global aerosol retrieval using SLSTR is based on algorithms developed under the ESA Aerosol Climate Change Initiative (CCI), to develop and evaluate the retrieval of aerosol properties and their uncertainties. Improvements to the products derived from ATSR-2 and AATSR have been developed under the same programme. This has led to generation of a 17-year dataset for global aerosol retrievals from ERS-2 and ENVISAT (1995-2012), and continued in the Copernicus Sentinel-3 series (2016-present). The datasets are evaluated using the global AERONET sun photometer network. Validation shows high correlation (R=0.8-0.9) of optical depth when compared against global AERONET measurements and low bias. The aerosol data from all the instruments is currently provided to both the UK Earth Observation Climate Information Service (UKCIS) and the Copernicus Climate Change Service (C3S). Recent improvements in the long-term archive, and results of testing new products from Sentinel-3 will be demonstrated, in particular improved retrievals over bright desert surfaces, and establishing continuity between the instrument records. The dataset is intended for use in climate modelling and benchmarking.

Name	Presentation title	Presentation Abstract
Qianqian Song	Resolving dust mineralogy in climate model: impacts on Earth's Radiation and Climate	One of the most important controlling factor of dust impacts on the Earth's climate systems is its mineralogical composition. For example, the key mineral(s) for specific interactions are for radiation (hematite-SW, quartz-LW), snow darkening (hematite), cloud properties (feldspar-ICN), ocean biogeochemistry (iron-bearing: hematite), ozone photochemistry (calcite, hematite). Despite the potential importance of resolving dust mineralogy in many aspects, current climate models tend to use fixed mineralogy without considering its temporal and spatial variation. To test the importance of resolving dust mineralogy on climate through its interactions with SW and LW radiation, we implemented and simulated the distribution of 9 minerals in the GFDL AM4 model.
Ranjitkumar Solanki	Effect of Lockdown on Aerosol Optical Depth using Satellite (MODIS Aqua and Terra), based observation over Surat	COVID-19 is evolving into one of the worst pandemics in recent history, claiming a death toll of over million as of December 2020. In an attempt to limit the expansion of the pandemic in its initial phase, nearly all countries-imposed restriction measures, which resulted in an unprecedented reduction of air pollution. This study aims to assess the impact of the lockdown effects due to COVID-19 on in satellite (MODIS Aqua and Terra) measured aerosol properties, namely Aerosol Optical Depth (AOD) in Surat, Gujrat. Moreover, a comparison is performed with the 2019 and 2020 at site. The study examines pre-lockdown (1–24 March 2020), lockdown (25 March – 31 May 2020) and post-lockdown (1-June to 31 Dec 2020) periods, while the aerosol properties are also compared with a one-year preceding period (2019). Comparison of meteorological parameters in Surat, between the lockdown period in previous years, showed variation, which is not deemed sufficient in order to justify the notable changes in aerosol concentrations and optical properties.
Reed Espinosa	Exploring the Impact of Imperfect Particle Shape Assumptions on Synergistic Lidar and Polarimeter Aerosol Retrieval Performance	Within a decade, the NASA led Atmosphere Observing System (AOS) mission plans to fly both a Multiangle, multispectral Polarimeter (MAP) and Elastic Backscatter Lidar (EBL) together on the same satellite platform. Coincident measurements from these two sensors will be combined to produce synergistic aerosol retrieval products simultaneously characterizing aerosol amount, microphysics, and vertical distribution. The increased information content in this synergistic dataset will represent a significant step forward in our ability to remotely sense aerosol from space but, for this additional information to be fully utilized, novel retrieval approaches will need to be developed and evaluated. In this talk we summarize the planned aerosol algorithms and products for AOS, while also highlighting some of the associated challenges. In particular, we will focus on the challenge of finding particle single scattering models that are able to accurately reproduce observations from both MAP and EBL instruments. Retrieval performance under different forward modeling errors is assessed by applying the Generalized Retrieval of Aerosol and Surface Properties (GRASP) algorithm to synthetic top-of-atmosphere polarimetric radiance and attenuated backscatter and depolarization profiles derived using different single scattering optics assumptions. Specifically, we perform retrieval simulations employing spherical, spheroid and hexahedral particle shape assumptions. In many studied scenes, we find that synthetic observations derived using spheroidal optics can differ from their hexahedral counterparts by an order of magnitude more than typical measurement uncertainties. Lidar backscattering and depolarization and Degree of Linear Polarization (DoLP) in MAP radiances all show particularly strong dependence on particle shape. In the retrieval products, the advantages of incorporating these additional measurements over purely passive, intensity only inputs are generally negated by the presence of these particle shape forward modeling errors.
Robert C Levy	Long-term, consistent, global and regional AOD climate data records: joining MODIS and VIIRS.	Using the Dark Target (DT) algorithm, aerosol optical depth (AOD) products are available for MODIS on Terra (M-T) and Aqua (M-A) as Collection 6.1, and VIIRS on Suomi-NPP (V-SNPP) and NOAA-20 (V-N20) as Version 2.0. M-T and M-A have overlapped since 2002, with V-SNPP and V-N20 entering the fray in 2012 and 2017. Despite differing overpass times, spatial resolution, calibration, and spectral band characteristics, all sensors using DT appear to generally "observe the same world". Although there is no significant trend to AOD on a global scale, there are regional trends and tendencies that appear to be significant. Over 20 years, we see overall decreases over eastern China, the eastern United States, much of Europe, and parts of Brazil, while increasing by roughly the same amount over India and the Arabian Peninsula. Yet over the past 10 years, the eastern U.S. and Europe has been flat (most of the decrease was prior to the VIIRS era), and that China's decrease is even stronger. In other words, a coherent regional trend does not imply constant change over time or that current trends can be expected to continue. Now that we have overall consistency when it comes to observing long-term trends, and that we can start to consider "success" in splicing VIIRS into the MODIS data record, what about absolute magnitudes of AOD? Assuming that two or more sensors provide similar-enough sampling of the AOD (in between ice/snow/clouds/glint), how precise can/should we be? We have a case study using twin sensors on GOES-17 and GOES-18. Let's discuss.

Name	Presentation title	Presentation Abstract
Ruben Sousse	Global simulations of nitric acid condensation on mineral dust aerosols using parameterizations of different complexity	Mineral dust is amongst the largest contributors to the global aerosol mass load and dominates climate effects over large areas of the Earth. Dust undergoes heterogeneous chemical reactions during transport, increasing its hygroscopicity and altering its optical properties and associated radiative forcing (Kok, 2022). The rates of heterogeneous chemical reactions on the dust surface that form coatings of sulfate, nitrate, chloride, or organics depend strongly on the dust mineralogical composition. For example, the uptake of sulfur dioxide by calcite exceeds by at least an order of magnitude uptake by quartz, feldspar and hematite. Dust mineral composition also affects the partitioning of semi-volatile inorganic compounds, altering their burden and radiative forcing (Usher, 2003). In this work, we assess the role of mineral dust on nitrate aerosol formation using model parameterizations of varying complexity. We have implemented aerosol nitrate formation on fine and coarse particles in the Multiscale Online Nonhydrostatic AtmospheRe CHemistry (MONARCH) model (Klose, 2021). We conduct global simulations and analyse the response to different treatments of nitric acid, ammonia and sulfate heterogeneous chemistry on dust aerosol. Globally homogeneous dust mineral composition is assumed, accounting for minerals that provide Ca2+, Mg2+, K+ and Na2+ non-volatile cations (NVC), determinants of aeolian dust pH. First-order uptake reactions are compared against approaches based on thermodynamic equilibrium assumptions, including the formation of subproducts from the gas-mineral interaction, and considering or not the effect of dust NVC upon aerosol pH. The different implementations are evaluated against observations and compared with literature results. Our preliminary findings highlight the important role of dust mineral content in dust aerosol chemistry, and the relevance that thermodynamic assumptions have when simulating the evolution of mineral dust in the atmosphere. We will discuss the changes in the production, burden and deposition of nitrate aerosols derived from the different modelling runs. These results represent the baseline for future sensitivity studies of factors affecting dust heterogeneous chemistry, such as regional variations in the mineralogical composition of dust.
Ruth Digby	How much of the uncertainty in black carbon ERF can be attributed to uncertainty in its refractive index?	The ERF of black carbon remains poorly constrained, with substantial uncertainty in black carbon emissions, lifetime, and optical properties, as well as in processes including mixing, ageing, and cloud interactions. Here we conduct a sensitivity test on what is perhaps the most easily quantifiable of many uncertain factors: the refractive index. We conduct three sets of simulations in CanAM-PAM, varying the refractive index of black carbon between three commonly used values: 1.75-0.44i (D'Almeida 1991), 1.75-0.63i (Bond and Bergstrom 2006), and 1.95-0.79i (Bond and Bergstrom 2006). The 2015-2019 global mean transient BC ARI increases nearly 50% between these ensembles, from 0.19 W/m2 to 0.28 W/m2, with statistically significant regional increases of up to 1 W/m2. The net shortwave ERF changes sign, increasing from -0.02 W/m2 to +0.10 W/m2. These results suggest that uncertainty in the refractive index of black carbon may contribute substantially to the spread in multimodel estimates of BC ERF.
Sarah Smith	A Solar Zenith Angle Dependency on Passive versus LiDAR Sensor AOD Retrieval Biases	Proper constraints on the seasonality of aerosol burdens are essential for quantifying the radiative effects of aerosols in the high latitudes, where insolation varies dramatically by season. Satellite measures of aerosol optical depth (AOD) are an essential component of global aerosol monitoring systems, and are particularly important in remote regions where other observational constraints are limited. In situ observations of surface-level aerosol optical properties at Arctic stations have long shown a pronounced seasonal cycle. This seasonality is also evident in high latitude (>60N) AODs from the LiDAR-based instrument CALIOP, but is not reflected in reanalysis AOD products (MERRA-2 and CAMSRA), or AODs from the passive sensors they assimilate (e.g. AERONET, AVHRR, MODIS, MISR, POLDER, SeaWiFS, VIIRS), even when controlling for seasonal differences in data availability. We find that seasonal differences in the bias between passive and active sensors can be explained by a significant and substantial dependency on the solar zenith angle, which is also apparent in the midlatitudes. We further examine the accuracy of each dataset in the context of mid-high latitude seasonality, and consider whether adjustments to the assimilation process may improve reanalysis products' representations of AOD seasonality.
Shenglong Zhang	Impacts of Anthropogenic Aerosol Emissions on the East Asian Winter Monsoon	Circulation patterns linked to the East Asian winter monsoon (EAWM) affect precipitation, surface temperature, and air quality extremes over East Asia. These circulation patterns can in turn be influenced by aerosol radiative and microphysical effects through diabatic heating and its influences on atmospheric vorticity. Using global model simulations conducted using the Tsinghua University Community Integrated Earth System Model (CIESM) for the AeroCom ACAM experiment, we investigate the effects of aerosol emissions and concentration changes on the intensity and variability of the EAWM. Comparison with reanalysis products indicates that the model captures the mean state and variability of the EAWM well. The experiments indicate that anthropogenic aerosol emissions strengthen the winter monsoon, leading to a stronger vorticity intrusion and colder conditions near the surface, especially in the northern part of East Asia. The mechanisms behind these changes are evaluated by analyzing the model heat and vorticity budgets. Further analysis of daily and sub-daily variability in the simulations is conducted to assess aerosol effects on the occurrence frequency and intensity of severe winter weather, such as cold air outbreaks and heavy snowfall.
Shuaiqi Tang	Earth System Model Aerosol-Cloud Diagnostics Package (ESMAC Diags): Evaluate Climate Models using Field Measurements from Aircraft, Ship, Surface and Satellite	We developed an Earth System Model (ESM) aerosol-cloud diagnostics package (ESMAC Diags) to facilitate the routine evaluation of aerosols, clouds and aerosol-cloud interactions simulated by the Department of Energy's (DOE) Energy Exascale Earth System Model (E3SM). The diagnostics package focuses on comparing simulated aerosol and cloud properties with in-situ and remote-sensing measurements from aircraft, ship, surface and satellite platforms. The diagnostics currently covers six field campaigns in four geographical regions: Eastern North Atlantic (ENA), Central U.S. (CUS), Northeastern Pacific (NEP) and Southern Ocean (SO). These regions produce frequent liquid or mixed-phase clouds with extensive measurements available from the Atmospheric Radiation Measurement (ARM) program and other agencies. An "aircraft simulator" is used to extract aerosol and meteorological model variables along flight paths that vary in space and time. Similarly, the aircraft simulator is applied to ship tracks in which the altitude remains fixed at sea level. ESMAC Diags includes various types of single-variable and multi-variable relations diagnostics, such as percentiles, histograms, joint histograms and heatmaps, to evaluate aerosols, clouds and aerosol-cloud interactions. We will present an overall introduction of ESMAC Diags, show examples on how E3SM represents aerosols, clouds and aerosol-cloud interactions in different climate regimes, and discuss mechanisms and factors that contribute to the model biases.

Name	Presentation title	Presentation Abstract
Susannah Burrows	Progress and challenges in simulating ice-nucleating particle concentrations for global climate models	Aerosols contribute globally not only to the direct radiative forcing of climate and impacts on warm clouds via cloud condensation nuclei, but also to populations of ice-nucleating particles (INPs) and their impacts on mixed-phase and ice clouds. Cloud and climate models increasingly aim to represent the complex interactions of INPs with cloud processes by implementing aerosol-aware parameterizations of ice nucleation. While these developments are exciting, aerosol-aware cloud and climate models are also susceptible to biases in simulated atmospheric INP populations. Until recenty, ice nucleation parameterizations and simulated INPs had not been systematically challenged with field observations. Our group has addressed this need through both observational closure studies and evaluations of model skill in simulating INP concentrations and their aerosol sources. We have focused on immersion-mode ice nucleation due to its importance for freezing in mixed-phase clouds. In recent case studies, we show that observational closure was achieved for both dust and sea spray INPs, while errors in simulated INPs were primarily attributable to errors in simulated aerosol surface area and composition. Important uncertainties in INP sources and parameterizations remain. Notably, warm-temperature INPs, often associated with biological or biogenic particles, are challenging to both observe and simulate. Nevertheless, at colder freezing temperatures (e.g., below -20 deg C), our results suggest that present-day INP parameterizations are likely adequate for simulating the first-order dependencies of INP concentrations on freezing temperature and aerosol amount. These results also highlight the importance of ensuring fidelity in simulations of natural aerosol sources, particularly dust, in models that link cloud ice nucleation to simulated aerosol properties.
Taufiq Hassan	Uncertainties of anthropogenic aerosol emission representation and the impact on the aerosol simulation in E3SM	Emission size distributions of primary anthropogenic aerosol particles are often prescribed in size-resolved global aerosol-climate models. They directly affect the simulated aerosol size distributions and lifecycle, especially near emission source regions. However, there is a large uncertainty in the assumed particle sizes in the literature. Here we investigate the impact of changing emission particle size distributions on aerosols and their radiative forcing in the Energy Exascale Earth System Model (E3SM) atmosphere model version 2 (EAMv2). Based on assumed emission sizes in the literature, we selected different particle sizes that determine the emission size distribution of black carbon (BC), primary organic matter (POM), and sulfate from different emission sectors. A reduction in BC/POM anthropogenic emissions size in E3SM leads to an increase in simulated aerosol number concentrations but a decrease in particle sizes in the primary carbon mode and accumulation mode. These changes become more pronounced with stronger perturbations. With the smallest assumed emission size, as suggested in the literature (an 18-fold increase in number emissions), EAMv2 simulates substantial changes in the simulated aerosol lifecycle and anthropogenic forcing. On the other hand, with larger assumed emission sizes for anthropogenic BC/POM, the aerosol number concentrations near source regions are significantly decreased, although the anthropogenic aerosol forcing is almost the same as in the reference simulations (with default emissions). The impact of emission sizes is also investigated for wildfire aerosol emissions and for primary sulfate from industry and energy sectors. Our results suggest that it is vital to constrain the uncertainty in the emission size distributions for primary emissions.
Tianle Yuan	Building a suite of machine learning models to predict PM2.5 from large-scale GEOS-GOCART model simulations and apply it to real data	In this presentation, we will present results from training a suite of machine learning models using data from GEOS-GOCART simulations. The goal is to predict PM2.5 concentrations from satellite observables and auxiliary data. The suite of models considers different configurations and complexity of observation data and model configurations. The training data contains the largest number of samples as far as we know. The suite of models shows excellent performance on test data set and good performance when applied to real observations. In other words, our models learn relationships from GEOS-GOCART model and still work for real observations. Our models also do not have geographic limitations and apply globally.
Velle Toll	Industrial aerosols glaciate liquid-water clouds, produce snow and reduce cloud cover	Anthropogenic aerosols could warm the Earth's climate by transforming supercooled liquid cloud droplets into ice crystals. However, it remains debated whether anthropogenic aerosols can induce such transformation. Here, we show that aerosols from metallurgy, cement production, coal-fired power plants and oil refineries glaciate liquid droplets at temperatures between -10 to -24 °C. Compared to the nearby unpolluted supercooled liquid-water cloud deck, the aerosol-polluted glaciated clouds backscatter 14% less solar radiation to space on average. The reduced backscatter results from a 10% reduction in cloud cover and a 23% reduction in the optical thickness of polluted clouds. In addition, daily aerosol-induced snowfall accumulations reach 15 mm. The aerosol-polluted areas with decreased cloud cover are plume-shaped, with a distinctive head pointing towards the pollution source, similar to aerosol-polluted cloud tracks in liquid-water clouds (Toll et al 2019 Nature https://doi.org/10.1038/s41586-019-1423-9). Our findings highlight an urgent need to quantify climate warming by aerosol-induced glaciation of clouds.

Name	Presentation title	Presentation Abstract
Yan Feng	Global Dust Cycle in the DOE E3SM version 3 (E3SMv3) Improvement in Emissions, Transport and Direct Radiative Forcing	Quantification of dust life cycle and radiative effects in Earth System Models has important implications for improving the model's capabilities to simulate water cycle and biogeochemistry in response to climate change. The present study examines the global dust cycle in the latest development of the U.S. DOE E3SMv3. Compared to E3SMv1 (part of CMIP6), we have made several major upgrades on dust-related processes in E3SMv3 including: (1) a new dust emission scheme based on time-varying soil edibility; (2) a new process coupling for dust transport; (3) updated dust refractive indices in shortwave and (4) more coarse-mode particles emitted at emission. As a result, E3SMv3 reduces the overestimation of dust aerosol absorption by nearly a factor of two, which is now in better agreement with the AERONET observations. Dry deposition is responsible for 73% of the global dust removal and a dust lifetime of 3 days in E3SMv3, consistent with the CMIP6 models (60%-86% and 1.8-6.8 days). The enhanced high-latitude dust emissions and long-range transport, as revealed by the comparison with satellite dust extinction profiles (CALIPSO), lead to the increased model prediction of ice nucleation particles, e.g., in the high-latitude mix-phased clouds. Overall, dust SW cooling in E3SMv3 is increased and agrees with Kok et al. (2017). But the comparison of dust LW DRF with recent modeling studies suggests that coarse particles (>10um) may still be underrepresented in E3SMv3, yielding a stronger cooling effect than the observationally based mean estimate: −0.2 Wm −2 (−0.48 to +0.2). Although the implementation of the time-varying soil erodibility improves the spatial and seasonal variability in dust sources compared with the observations in the modern days, the long-term trend in historical changes of dust loading is still weak in the model.
Yawen Liu	A Strong Anthropogenic Black Carbon Forcing Constrained by Pollution Trends Over China	Estimates of the effective radiative forcing from aerosol-radiation interaction (ERFari) of anthropogenic Black Carbon (BC) have been disputable and require better constraints. Here we find a substantial decline in atmospheric absorption of −5.79Wm−2decade−1 over eastern central China (ECC) responding to recent anthropogenic BC emission reductions. By combining the observational finding with advances from Coupled Model Intercomparison Project phase6 (CMIP6), we identify an emergent constraint on the ERFari of anthropogenic BC. We show that across CMIP6 models the simulated trends correlate well with simulated annual mean shortwave atmospheric absorption by anthropogenic BC over China. Making use of this emergent relationship allows us to constrain the aerosol absorption optical depth of anthropogenic BC and further provide a constrained range of 2.4–3.0 Wm−2 for its top-of-atmosphere ERFari over China, higher than existing estimates. Our work supports a strong warming effect of BC over China, and highlights the need to improve BC simulations over source regions.
Yunpeng Shan	Aerosol radiative forcing in E3SM: improvements from aerosol wet removal treatment and parameter tuning	Effective radiative forcing of anthropogenic aerosols (ERFaer) is an important metric to quantify the simulated aerosol effects on climate, which remains the largest uncertainty in climate prediction using global climate models. Many models simulate overly strong ERFaer and its direct and indirect forcing components (ERFari and ERFaci), including Department of Energy's Energy Exascale Earth System Model (E3SM). For E3SM, one important reason is the overestimated burden and lifetime of anthropogenic aerosols, which is attributed to the insufficient aerosol wet removal. By improving aerosol wet removal treatments for deep convective clouds (e.g., cloud-borne aerosol detrainment, aerosol secondary activation, and cloud-borne aerosol removal), we effectively decrease the aerosol burden and lifetime, and reduce the positive biases in aerosol optical depth and aerosol mass concentration in E3SM. The ERFari and ERFaci, and the bias in the TOA radiation budget are also significantly decreased. We further increase the hygroscopicity of primary organic matter, which has a large impact on the black carbon lifetime. This helps to reduce the biases related to black carbon and provide a more reasonable estimate of ERFari (-0.15 W m-2 versus the original 0.17 W m-2). Tuning the cloud microphysics parameters and imposing a lower bound of cloud droplet number concentrations can further reduce the ERFaci. As a result, our improved model decreases the ERFaer at TOA to -0.9 W m-2 and the decomposed forcings are also well within the reference ranges. Additionally, the ERFaer at surface decreases to -2.07 W m-2 (versus the original -3.25 W m-2). These changes help improve the simulated historical surface temperature changes in the coupled model simulation.
Zheng Lu	CCNs and aerosols over the Eastern North Atlantic from DOE E3SM, NCAR CESM and AeroCom III models and implications for aerosol indirect forcing	Marine boundary layer (MBL) clouds play an important role in the climate system because of their strong ability to affect radiative budget by reflecting the solar radiation. The macro- and microphysical properties of MBL clouds are very sensitive to the cloud condensation nuclei (CCN) concentrations and hence to the aerosol properties. Here we examine the CCN and aerosol simulations in the MBL over the Eastern North Atlantic from the DOE's Energy Exascale Earth System Model (E3SMv1), the NCAR's Community Earth System Model (CESMv2.1) and the AeroCom phase III models. Large differences are found in the CCN magnitudes and spatial distributions over the North Atlantic. We then evaluate the modeled aerosol and CCN fields against the aircraft measurements during the Atmospheric Radiation Measurement (ARM) Aerosol and Cloud Experiments in the Eastern North Atlantic campaign (ACE-ENA) and surface observations at the ARM ENA site in Azores from 2014 to 2018. Our results show these models can generally capture the CCN seasonal cycle at surface with a peak in July. However, substantial differences in the vertical profiles of CCNs are found among these models. To understand reasons behind the discrepancies in these model simulations, we run sensitivity experiments using the E3SM model and examine the impact of different aerosol treatments on CCN and aerosol sources and abundances in the MBL and implication for aerosol indirect radiative forcing, by perturbing the DMS emissions, and the injection altitude of biomass burning aerosols and secondary organic aerosols.